COSEWIC
Assessment and Status Report

on the

Eastern Waterfan
Peltigera hydrothyria

in Canada

THREATENED
2013

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2013. COSEWIC assessment and status report on the Eastern Waterfan *Peltigera hydrothyria* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 46 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Production note:
COSEWIC would like to acknowledge David H. S. Richardson, Frances Anderson and Robert Cameron for writing the status report on the Eastern Waterfan, *Peltigera hydrothyria*, in Canada, prepared under contract with Environment Canada. This report was overseen and edited by René Belland, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Peltigère éventail d'eau de l'Est (*Peltigera hydrothyria*) au Canada.

Cover illustration/photo:
Eastern Waterfan — provided by authors.

©Her Majesty the Queen in Right of Canada, 2014.
Catalogue No. CW69-14/685-2014E-PDF
ISBN 978-1-100-23556-1

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – November 2013

Common name
Eastern Waterfan

Scientific name
Peltigera hydrothyria

Status
Threatened

Reason for designation
This rare lichen is endemic to Eastern North America. In Canada, it is known only from New Brunswick, Nova Scotia and Quebec. It grows at or below water level in cool, clear, partially shaded streams. It is threatened in the short term by disturbance from activities which cause stream siltation, alteration of microclimate and declines in water quality. In the longer term, changes in weather patterns that alter water levels and flow in its preferred habitat are another threat.

Occurrence
Quebec, New Brunswick, Nova Scotia

Status history
Designated Threatened in November 2013.

COSEWIC
Executive Summary

Eastern Waterfan
Peltigera hydrothyria

Wildlife Species Description and Significance

The Eastern Waterfan, *Peltigera hydrothyria,* is a leafy lichen having veins on the under surface that are distributed in a fan-shaped manner. The lichen is fixed to rocks by spongy tufts of fibres. The red-brown fruit bodies are borne on the margin of the lichen. The sacs within the fruit bodies shoot out elliptical spores. There are no specialized vegetative propagules. The photosynthetic partner in this lichen is a cyanobacterium. This species is one of only a few leafy lichens that can grow at and below water level.

Distribution

The Eastern Waterfan is endemic to eastern North America. In the USA, this lichen occurs at approximately 30 sites scattered throughout Connecticut, Georgia, Maine, Massachusetts, New Hampshire, North Carolina, Pennsylvania, Rhode Island, Tennessee, Vermont and Virginia.

In Canada, the Eastern Waterfan is currently known only from three provinces: Québec, New Brunswick and Nova Scotia. There are thirteen sites comprising ten occurrences and seven locations. A site is where the lichen is actually found, and sites less than 1km apart comprise a single occurrence. A location is a geographically or ecologically distinct area in which a single threatening event can rapidly affect all the individuals present at an occurrence. There is one occurrence of the Eastern Waterfan in Québec, three in New Brunswick and six in Nova Scotia. The Canadian population of the Eastern Waterfan represents approximately one-quarter of the known world total. There are no historical occurrences from Ontario, Prince Edward Island or Newfoundland and Labrador.

Habitat

In eastern North America, the Eastern Waterfan grows attached to rocks at or below water level in clear, cool, partially shaded streams. Small waterfalls, exposed boulders and sinuous stream configurations create quiet or protected backwaters where the lichen grows outside the main current. In summer, this lichen is often partially or completely exposed during low water flow periods. The elevation of streams in which the Eastern Waterfan is found varies from 10m to 720m a.s.l. Stream quality, including a suitable pH, water temperature, and absence of silt, appears to be very important. Partial shade may be needed to help keep humidity high and temperatures low during summer months. Stream water temperature appears to be very important. Studies on the related Western Waterfan show that if the temperature reaches 18°C, photosynthetic rates decline and thallus weight loss occurs after only 30 days. Nitrate levels at or above 5mM lead to a similar decline.

Biology

The Eastern Waterfan produces no specialized vegetative propagules but it is likely that small pieces of lichen break off and become attached downstream to provide a means for dispersal. The only other way the lichen can reproduce is via the discharge of fungal spores from the apothecia but success depends upon the presence of a suitable cyanobacterium for resynthesis of the lichen. The fruit bodies of the lichen eject their spores into the air. Upon landing on a rock surface in or on the banks of a stream, these germinate and grow towards nearby cyanobacteria. If the latter are compatible, they become enveloped by the fungal strands and eventually grow into a visible lichen. The generation time for lichens varies from ten years in rapidly colonizing lichens to more than 17 years for old-growth forest species.

The Eastern Waterfan is a member of a group of lichens known as cyanolichens in which cyanobacteria provide carbohydrates through photosynthesis to the fungal partner as well as nitrogen since they are able to fix atmospheric nitrogen. The cyanobacterium in the Eastern Waterfan is reported to be *Capsosira lowei.*

Population Sizes and Trends

The abundance of the Eastern Waterfan at the ten occurrences varies greatly, from 12 to 484 mature individuals (colonies).The total enumerated population of the Eastern Waterfan is 1,282 mature individuals. In some streams, one or a small number of individuals (colonies) were found, while in other streams almost every rock in up to 5m stretches were colonized. In such areas, 100 or more colonies occurred and were a problem to count accurately as it was difficult to determine where one individual ends and the next begins.

Further surveys may reveal a few more occurrences for this lichen, but it is likely that the total population of the Eastern Waterfan in Canada will not exceed 2,000 colonies, taking into account the many streams where this species was searched for but not found.

There are no historical records of the Eastern Waterfan in Maritime Canada before 1978. Those found since were only re-visited in 2011 so there is insufficient documented evidence to assess trends or fluctuations in the population.

Threats and Limiting Factors

Activities that alter the watercourses, water quality and protective vegetation surrounding habitats all have the potential to affect Eastern Waterfan locations. Cool water appears to be crucial to the Eastern Waterfan's ability to thrive. Removal of trees growing near stream banks exposes the Eastern Waterfan to increased sun, raised air temperatures, reduced humidity and increased erosion and runoff. Increased wind and light exposure in harvested areas can reduce water levels on and around rocks where the Eastern Waterfan occurs so that during months with low water levels, the lichen may be exposed and become dry beyond its tolerance limits. Forestry activities in Colchester County, Nova Scotia, may currently affect five of the seven locations of this lichen and over 30% of the total enumerated mature individuals in Canada. The need to supply 500,000 tons of wood annually for the new 60-megawatt biomass electricity co-generating station in Nova Scotia will mean greater forestry activity and habitat disturbance. Currently, forest harvesters in Nova Scotia are only required to leave a 20m buffer on each side of streams; it is 30m in New Brunswick.

The further expansion of wind farms in Nova Scotia, forestry activity, or mineral exploration also requires access roads through undisturbed woodlands. These may encroach on existing Eastern Waterfan habitats and be a source of siltation, which has the potential to affect several of the Eastern Waterfan sites. The extraction of natural gas through hydrofracturing is also known to alter groundwater patterns and water quality. Two areas in Nova Scotia where the Eastern Waterfan occurs are being considered for this activity. The Eastern Waterfan grows only in semi-shaded streams with little to no siltation. Repeated siltation events caused by runoff from roadbeds or motorized vehicle tracks can coat the lobe surfaces of the lichen, affect photosynthesis and cover potential sites for establishment on rock surfaces.

Air pollution can affect lichens. Acid rain, currently less serious in the Maritimes than in former decades, may eventually result in the buffering capacity of the watersheds or substrata being exceeded. This may lead to the water becoming more acidic and this could prevent cyanolichens like the Eastern Waterfan from thriving.

Climate change in the medium term is a serious threat to most of the Eastern Waterfan locations. Recent models suggest that the amount of summer precipitation in Nova Scotia is not expected to change much, but there will be more droughts due to increased evaporation as a result of higher summer temperatures. Droughts reduce water flow and stream depth, which can lead to desiccation and death of the Eastern Waterfan. In winter the climate models suggest there will be more precipitation of which a higher proportion will fall as rain. The increased water flow is likely to enhance scouring and remove the Eastern Waterfan from rocks on the margins and bottoms of streams.

Protection, Status, and Ranks

In Canada, the Eastern Waterfan is ranked by NatureServe as SNR (unranked at a national or subnational conservation level: status not yet assessed). The General Status of Species in Canada lists it as May Be at Risk in Québec and also for Nova Scotia, and as Undetermined for New Brunswick. NatureServe lists the Waterfan as N2 (imperiled) for Canada as of 09 Sept 2011.

In New Brunswick, two of the three occurrences for the Eastern Waterfan are currently protected by being in Fundy National Park. At the other occurrence, there is no protection as the streams flow through Crown and private land. Two of the six occurrences in Nova Scotia are protected: one is in Cape Chignecto Provincial Park and the second is on Crown land near the Pollett's Cove-Aspy Bay Wilderness Area. The Québec occurrence is now protected via a biodiversity conservation project called Réserve de biodiversité projetée de la Forêt-Montmorency.

In the USA, the Eastern Waterfan is ranked as S1 (critically endangered) in Virginia, and S3 (vulnerable) in North Carolina. It has not yet been ranked in Connecticut, Georgia, Maine, Massachusetts, New Hampshire, Pennsylvania, Rhode Island, Tennessee, or Vermont.

TECHNICAL SUMMARY

Peltigera hydrothyria

English common name:
Eastern Waterfan

Nom commun français :
Peltigère éventail d'eau de l'Est

Range of occurrence in Canada (province/territory/ocean): Québec, New Brunswick, Nova Scotia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	Between 10 and 30 years, likely around 17 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. Disturbance and forestry operations close to three of the ten occurrences could lead to the disappearance of 30% of the known population within three generations (50 years)	Inferred reduction of 30%
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Understood but not ceased
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	96,800 km^2
Index of area of occupancy (IAO)	36 km^2
Is the total population severely fragmented? The Eastern Waterfan has been found at thirteen sites. There are four in New Brunswick, one in Québec and eight in Nova Scotia. Six of the thirteen sites have less than 30 colonies so the viability of the population is in doubt. These sites comprise ten occurrences. The occurrences are more than 20km apart and the Eastern Waterfan has no specialized vegetative propagules and the sexual spores are likely have a limited dispersal. The latter, upon germination, also require a compatible cyanobacterium for thallus formation.	Maybe
Number of locations*.	7

* See definition of location: COSEWIC Operations and Procedures Manual, August, 2013, Appendix C, p.149

Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Yes, observed and inferred by threats to the habitat
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? See above projected % reduction in number of individuals.	Yes, inferred
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Yes, inferred
Is there an [observed, inferred, or projected] continuing decline in number of locations?	Yes, inferred
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Habitat threatened by siltation and change in microclimate due to activities that include forestry, road construction in the short term and climate changes in the long term.	Yes observed and inferred decline in quality of habitat
Are there extreme fluctuations in number of populations?	Unlikely
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
NB based on 2013 estimates (Table 2)	284
QC based on 2012 estimates (Table2)	12
NS based on 2012 estimates (Table2)	986+
Total	1282+ <2000 estimated

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not done

Threats (actual or imminent, to populations or habitats)

The main threats are forestry and human activities, especially road construction related to forestry and wind-farm construction that that alter the watercourses, water quality, or increase siltation. Forest harvesting, including that for biomass electricity generation, is likely to increase sunlight, raise water temperatures, as well as reduce summer water levels and humidity. This can affect the survival of current Eastern Waterfan populations. In the longer term climate change is predicted to lead to warmer summers that would reduce stream flow and levels, again leading to the disappearance of *P. hydrothyria* populations.

Rescue Effect (immigration from outside Canada)

P. hydrothyria occurs in the Appalachians and is ranked S1, critically endangered, in Virginia and S3, vulnerable in North Carolina. It has not been ranked in Connecticut, Georgia, Maine, Massachusetts, New Hampshire, Pennsylvania, Rhode Island, Tennessee or Vermont but has disappeared from at least three New England states.

Is immigration known or possible?	Yes but unlikely

Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Status History

COSEWIC: Designated Threatened in November 2013

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric Code:** C2a(i)
Reasons for Designation: This rare lichen is endemic to eastern North America. In Canada, it is known only from New Brunswick, Nova Scotia and Québec. It grows at or below water level in cool, clear, partially shaded streams. It is threatened in the short term by disturbance from activities which cause stream siltation, alteration of microclimate and declines in water quality. In the longer term, changes in weather patterns that alter water levels and flow in its preferred habitat are another threat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not meet criterion. There is insufficient data to determine the magnitude of declines.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criterion. There are potentially more than 10 locations.
Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened C2a(i) with fewer than 10,000 individuals (actual = 1282), an inferred continuing decline in the number of mature individuals and no subpopulation estimated to contain greater than 1000 mature individuals.
Criterion D (Very Small or Restricted Population): Does not meet criterion. The population is estimated to have more than 1000 individuals and the number of locations is greater than 5.
Criterion E (Quantitative Analysis): Not done.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2013)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada | Environnement Canada
Canadian Wildlife Service | Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Eastern Waterfan

Peltigera hydrothyria

in Canada

2013

TABLE OF CONTENTS

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE 5
- Name and Classification 5
- Morphological Description 5
- Population Spatial Structure and Variability 7
- Designatable Units 7
- Special Significance 7

DISTRIBUTION 8
- Global range 8
- Canadian Range 9
- Search Effort 11

HABITAT 19
- Habitat Requirements 19
- Habitat Trends 24

BIOLOGY 24
- Life Cycle and Reproduction 24
- Herbivory and Predation 25
- Physiology and Adaptability 25
- Dispersal and Migration 26
- Interspecific Interactions 27

POPULATION SIZES AND TRENDS 28
- Sampling Effort and Methods 28
- Abundance 28
- Fluctuations and Trends 28
- Rescue Effect 29

THREATS AND LIMITING FACTORS 29
- Siltation and Decreased Water Quality 29
- Decrease in Water Quantity 32
- Climate Change 32
- Air Pollution 34

PROTECTION, STATUS, AND RANKS 36
- Legal Protection and Status 36
- Non-Legal Status and Ranks 37
- Habitat Protection and Ownership 37

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED 38
INFORMATION SOURCES 39
BIOGRAPHICAL SUMMARY OF REPORT WRITER 44
COLLECTIONS EXAMINED 45

List of Figures

Figure 1. The life cycle of *Peltigera hydrothyria*: 1. Upper surface of thallus with apothecia (d); 2. Lower surface of thallus with fan-shaped veins; 3. Section of thallus and apothecium (a asci, b underlying hymenium, c cyanobacteria among fungal hyphae, lower cortex); 4. Section through thallus with the contained cyanobacteria and vein cut transversely; 5. An ascus with the contained fungal spores; 6. Close-up of an ejected spore showing shape and septation (from Schneider 1897). 6

Figure 2. The distribution of *Peltigera hydrothyria* in the USA (map: R. Cameron). 8

Figure 3. The distribution of *P. hydrothyria* in Canada. The pale yellow circles mark the occurrences where the lichen has been found, and the open circles show where streams have been searched unsuccessfully. Note that the occurrence is strongly correlated with a high moisture index, indicating the importance of high habitat humidity to this lichen. Humidity sectors are shown in the Atlantic Maritime Ecozone. Perhumid climate areas (moisture index of 100) are shown in dark green and very humid climates in medium green (index 80-99) (see Clayden 2010) (map R. Cameron). 18

Figure 4. The habitat of *Peltigera hydrothyria* at Black Brook in Fundy National Park, New Brunswick. The lichen occurs on the stream margins, behind boulders and in backwaters (Photo: F. Anderson). 20

Figure 5. *Peltigera hydrothyria* growing below water level on a stream bed of Carter's Lake Brook in dappled sunlight in clear water. The lichen is in the centre as well as in the upper and middle right (photo: D. Richardson). 21

Figure 6. *Peltigera hydrothyria* site at Daniels Brook, Shepody Mountain, New Brunswick, an atypical habitat for this lichen in Atlantic Canada (photo: F. Anderson). 23

Figure 7. A recent clear-cut adjacent to Carter's Lake Brook tributary that is colonized by *Peltigera hydrothyria* in the Cobequid Mountains (photo D. Richardson). 30

Figure 8. Siltation following heavy rain observed in Eatonville Brook, Cape Chignecto, which originated from forestry activity outside the park. This silt was brought in by an inflowing stream (photo: F. Anderson). 31

Figure 9. Proposed areas for hydrofracturing activities associated with shale gas extraction (Anon. 2011). Note that *Peltigera hydrothyria* occurs in two areas: the yellow area, labelled Eastrock Resources Ltd., includes the Cape Chignecto occurrence and the purple area north of Truro is close to the Colchester Co. occurrences 33

List of Tables

Table 1. The seven locations, ten occurrences and thirteen sites where *P. hydrothyria* has been found in Canada together with an estimate of the number of mature individuals (colonies) at each location. (The + sign indicates where it was difficult to enumerate the lichen as it was common and it could not be determined where one colony ended and the next began. Note: A site is where the lichen under study was actually found and the position recorded using GPS. When two or more sites were less than 1 km apart, they comprised a single occurrence. If two sites were more than 1 km apart, they were considered to be two occurrences. One or more occurrences that are affected by the same major threat or threats are defined as a location (in the IUCN sense that is used by COSEWIC) 9

Table 2. Information on the sites in Canada where *Peltigera hydrothyria* has been found in the provinces of Nova Scotia, New Brunswick and Québec. 12

Table 3. Brooks that were searched without results for *Peltigera hydrothyria* in 2011 and 2012 by Frances Anderson, Tom Neily and David Richardson in Nova Scotia and by Frances Anderson and Ben Phillips in New Brunswick. Many of the brooks have no name, so the nearest identifiable place appears in column 1. The percentage of the brook searched depended in part on the suitability of habitat conditions in and around the brook. DNC = data not collected. UTM = NAD83. 13

Table 4. Streams in the Maritime provinces and Québec that were searched by Stephen Clayden without finding *Peltigera hydrothyria*. 13

Table 5. The results of the Threats Classification and Assessment Calculator exercise for *P. hydrothyria*. 13

Table 6. Details of the threats faced by *Peltigera hydrothyria* at the various occurrences in Québec, New Brunswick and Nova Scotia. 15

List of Appendices

Appendix 1. GPS and other information on the sites in Canada where *Peltigera hydrothyria* has been found in the provinces of Nova Scotia, New Brunswick and Québec. 46

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Name: *Peltigera hydrothyria* Miadlikowska & Lutzoni (2000). Basionym: Type specimen – U.S.A. New Hampshire, Cheshire Co, Mt Brattleboro 16.vii 1851, J.L. Russell. Lectotype NY (Lendemer & O'Brien 2011).

Classification: In North America the genus *Peltigera* is represented by 37 species and classified in the family Peltigeraceae, order Peltigerales, class Lecanoromycetes, and division Ascomycota (Esslinger 2010).

The Eastern Waterfan was originally placed in its own genus *Hydrothyria* by Russell (1853) and was named by him as *Hydrothyria venosa* J.L. Russell *et al.* (2000) transferred this lichen to the genus *Peltigera*, but the name *P. venosa* could not be used because of the pre-existence of *P. venosa* (L.) Hoffm. A new name based on Russell's type was required and the name *Peltigera hydrothyria* was selected.

Common name: The name 'Watershield' was given to this lichen by Russell (1853) because of its aquatic habit and its distinct shield-like apothecia. However, because a common floating water plant, *Brasenia schreberi,* is also known as Watershield, the use of another common name avoids confusion. The former *Hydrothyria venosa* complex has been called the 'Waterfan' (Brodo *et al.* 2001). An appropriate common name is therefore 'Eastern Waterfan' for *P. hydrothyria* and 'Western Waterfan' for the very similar species, *P. gowardii*, which has recently been distinguished as a separate species (Lendemer & O'Brien 2011). The latter is endemic to western North America and a separate COSEWIC report has been prepared for it.

The French common name for *Peltigera hydrothyria* 'Peltigère bouclier' was suggested by Claude Roy who discovered this lichen in Québec.

Morphological Description

Peltigera hydrothyria is an aquatic, foliose lichen bearing distinct shield-like apothecia. Another striking peculiarity is the strongly veined undersurface: the veins traverse the thallus in a fan-shaped manner (Figure 1). The lichen fixes itself to the substratum by spongy tufts of strong fibres which grow from the veins. The red-brown apothecia are borne on the edges or margin of the thallus and occur frequently within a notch or sinus. They are sub-pedicellate and have a broad thalline exciple lacerated on the margin, which disappears with age leaving the apothecia somewhat convex. The disk is bright chestnut-coloured. There are eight sharply elliptical spores in each ascus that have two or three transverse septa. Vegetative propagules in the form of soredia and isidia are lacking in *P. hydrothyria*.

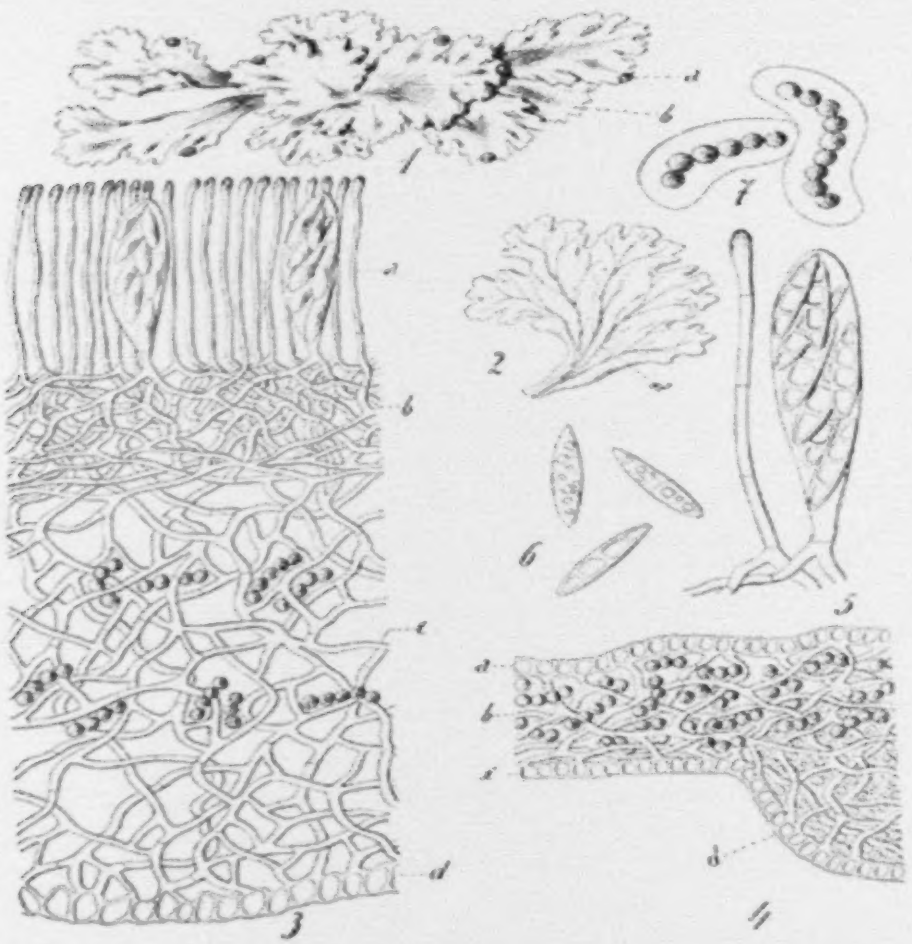

Figure 1. The life cycle of *Peltigera hydrothyria*: 1. Upper surface of thallus with apothecia (d); 2. Lower surface of thallus with fan-shaped veins; 3. Section of thallus and apothecium (a asci, b underlying hymenium, c cyanobacteria among fungal hyphae, lower cortex); 4. Section through thallus with the contained cyanobacteria and vein cut transversely; 5. An ascus with the contained fungal spores; 6. Close-up of an ejected spore showing shape and septation (from Schneider 1897).

The colour of the thallus when wet is almost black. In sunlight, under water, it acquires a reddish cast. The upper surface is shades of lead grey when dry, becoming brownish in older parts of the thallus. The lower surface is paler grey with raised, pale beige, occasionally pubescent veins. Older lobes may appear brownish below. Unlike other species of *Peligera*, but like many cyanobacteria-containing lichens, *P. hydrothyria* becomes somewhat translucent and jelly-like when wet. When fresh, the thalli have an aroma not unlike that of the bark of black birch, *Betula lenta* (Russell 1853, Schneider 1897). The closely related *P. gowardii* has been separated on the basis of molecular data, the absence of lichen substances, geographical distribution and ecological preferences (Lendemer & O'Brien 2011).

Chemistry: In *P. hydrothyria*, methylgyrophorate and methyllecanorate have been identified using thin layer chromatography and sometimes traces of gyrophoric or lecanoric acid are found (which give a C+pink reaction to acetone extracts). However, all spot tests are negative and there is no fluorescence under ultraviolet light (Lendemer & O'Brien 2011).

Population Spatial Structure and Variability

Recent work on the phylogeny of *P. hydrothyria* suggests there is no genetic, ecological, or morphological information to suggest differentiation between populations in eastern North America (Lendemer & O'Brien 2011, Lendemer & Anderson 2012).

Designatable Units

One designatable unit is recognized *for P. hydrothyria*.

Special Significance

Only a few macrolichens worldwide have adapted to grow below the water surface of rivers and streams. *P. hydrothyria* is endemic to eastern North America and is renowned for its ability to colonize this unusual habitat.

DISTRIBUTION

Global range

Peltigera hydrothyria is endemic to eastern North America (Figure 2). In the USA, most records are from the Appalachian Mountains in Connecticut, Georgia, Maine, Massachusetts, New Hampshire, North Carolina, Pennsylvania, Rhode Island, Tennessee, Vermont and Virginia (Dennis *et al.* 1981; Gary Perlmutter pers. comm. 2011; Don Flenniken pers. comm. 2011). It has disappeared from at least three New England States (Hinds & Hinds 2007), but it was recently found in Berkshire County, Massachusetts (Scott LaGreca pers. comm. 2011). The southernmost sites are in White County and Gilmer County, Georgia (William Buck pers. comm. 2011; Sean Beeching pers. comm. 2011).

Figure 2. The distribution of *Peltigera hydrothyria* in the USA (map: R. Cameron).

Canadian Range

The current known distribution of *P. hydrothyria* in Canada is restricted to three provinces: Québec, New Brunswick and Nova Scotia (Table 1 and Figure 3). There are no current or historical records from Ontario, Prince Edward Island or Newfoundland and Labrador. The Canadian occurrences of *P. hydrothyria* represent approximately one-quarter of the known world total.

Table 1. The seven locations, ten occurrences and thirteen sites where *P. hydrothyria* has been found in Canada together with an estimate of the number of mature individuals (colonies) at each location. (The + sign indicates where it was difficult to enumerate the lichen as it was common and it could not be determined where one colony ended and the next began. Note: A site is where the lichen under study was actually found and the position recorded using GPS. When two or more sites were less than 1 km apart, they comprised a single occurrence. If two sites were more than 1 km apart, they were considered to be two occurrences. One or more occurrences that are affected by the same major threat or threats are defined as a location (in the IUCN sense that is used by COSEWIC).

Location number and the estimated number of mature individuals (colonies)	Occurrence number	Site number and name of ntream where P. hydrothyria found	Main threat
One (484 + colonies)	**One** Albert Co New Brunswick	One Black Brook Fundy National Park, Albert Co	Climate change (reduced fog) and upstream forestry
	Two Albert Co New Brunswick	Two Dickson Brook Fundy National Park, Albert Co	
	Three Albert Co New Brunswick	Three Daniels Brook Shepody Mtn, Albert Co	
		Four Hamilton Creek West Shepody Mtn, Albert Co	
	Four Cumberland Co Nova Scotia	Five Eatonville Brook Cape Chignecto, Cumberland Co	
Two (150 colonies)	**Five** Colchester Co Nova Scotia	Six Carter's Lake Brook Folly Lake, Cobequid Mtns. Colchester Co	Wind turbines, construction and associated roads (siltation), Forestry activities (habitat disturbance and siltation), Climate change (warmer summers and reduced water flow)
		Seven Carter's Lake Brook Tributary Folly Lake, Cobequid Mtns Colchester Co	

Location number and the estimated number of mature individuals (colonies)	Occurrence number	Site number and name of ntream where P. hydrothyria found	Main threat
Three (100 colonies)	**Six** Colchester Co Nova Scotia	Eight A tributary of Beaver Brook in the Gerrish Valley, Colchester Co	Forestry activities (habitat disturbance and siltation), Climate change (warmer summers and reduced water flow)
Four (501+ colonies)	**Seven** Guysborough Nova Scotia	Nine West River Lake Brook Guysborough Co	Forest removal and human disturbance including road building
		Ten Melopseketch brooklet Guysborough Co	
Five (12 colonies)	**Eight** Richmond Co Nova Scotia	Eleven Embree's Brook tributary Port Hawksbury, Richmond Co	
Six (23 colonies)	**Nine** Victoria Co Nova Scotia	Twelve Gray's Hollow Brook North River Cape Breton Victoria Co	Upstream forest removal
Seven (12 colonies)	**Ten** Montmorency Co Québec	Thirteen Rivière Noire, la Forêt Montmorency Co	Former nearby forest removal

Nova Scotia:

In Nova Scotia, there are currently six known occurrences. The first discovery of *P. hydrothyria* in the province was made by Wolfgang Maass (pers. comm. 2003) from a stream that flows from Carter Lake into Folly Lake in the Cobequid Mountains. However, there is no voucher specimen in the Nova Scotia Museum or any published reports to document the date accurately. Subsequently, Frances Anderson found the lichen in Cape Chignecto Provincial Park and Tom Neily found it in the Port Hawkesbury area and in Guysborough County. Robert Cameron found *P. hydrothyria* at Gray's Hollow Brook in Cape Breton and Frances Anderson found it near Economy Mountain (in the Gerrish Valley) in a tributary of Beaver Brook, Colchester County (Table 2).

New Brunswick:

There are three occurrences of *P. hydrothyria* in New Brunswick. It was first discovered by Sharon Gowan in 1978 in Daniels Brook, Shepody Mountain, Albert County. A second occurrence on Shepody Mountain, just under 1 km away, was discovered in 2011 by Ben Phillips. Gowan also collected *P. hydrothyria* in Fundy National Park in 1980 from Bennett Brook and a tributary. Bennett Brook was searched in 2011 and *P. hydrothyria* was not found, but it did occur in a small unnamed tributary of that brook. The lichen was reported to be "rare on mossy rocks under fast moving water in small woodland streams" (Gowan & Brodo 1988). Finally, *P. hydrothyria* was found very recently (July 2013) by Ben Phillips in Dickson Brook, a few kilometres from the other record from Fundy National Park.

Québec:

In Québec there is a single occurrence of *Peltigera hydrothyria*. It was first discovered in the province by Claude Roy in 1990 at la Rivière Noire, within the reserve of la Forêt Montmorency. The site was revisited in 1995, 2003 and 2011.

Search Effort

There is a long history of lichen collecting in eastern Canada documented by a number of sources including Goward *et al.* (1998) and Clayden (2010). Even more search effort has been directed to the eastern USA, and in spite of there being a very active group (>30) of professional and amateur lichenologists (the Tuckerman Group), working in this region over the past 20 years, only 30 sites are known for *P. hydrothyria* over the whole Appalachian chain there. Of the five New England states in which it has been found historically, it is now known only in Massachusetts and Maine (Hinds & Hinds 2007). It appears to have very specific but not yet completely understood habitat requirements (see Habitat Requirements).

Only recently has research focused on finding the very distinctive and easily identified lichen *P. hydrothyria* in Canada. Discoveries in Atlantic Canada have occurred during general lichen or cyanolichen surveys by Tom Neily and by the writers of this COSEWIC report (especially Anderson 2004-2007) in Nova Scotia, and by Stephen Clayden and Ben Phillips in New Brunswick. Earlier, Clayden carried out extensive lichen surveys in New Brunswick, including the central New Brunswick highlands. Although he did not search specifically for *P. hydrothyria* in these surveys, he and others have examined stream habitats in many areas of the province.

Tom Neily and Frances Anderson conducted targeted surveys in Nova Scotia, searching the wet rocky margins of over 59 streams for aquatic lichens. *P. hydrothyria* was found at Cape Chignecto and Port Hawkesbury during these surveys. Even more focused searches for *P. hydrothyria* began in 2011 (Table 2). An additional 39 streams were searched but *P. hydrothyria* was not found (Table 3). Further searches were carried out in 2012 of nine streams in Cumberland and Colchester counties, on the basis of topography, accessibility, and experience identifying the type of streams colonized by this lichen (Table 3). The 2012 searches yielded one additional occurrence for *P. hydrothyria* in the Gerrish Valley, Colchester County.

Table 2. Information on the sites in Canada where *Peltigera hydrothyria* has been found in the provinces of Nova Scotia, New Brunswick and Québec.

Site name of stream	Year found	Most recent survey	Estimated number of colonies	Elevation	Stream pH	% of stream searched	Ownership / Protection
NEW BRUNSWICK							
Black Brook, Fundy National Park	1980	July 2011	5	248-252m	6.8-7.1	30%	National Park
Dickson Brook, Fundy National Park	2013	July 2013	200	66-94	7.2-7.3	70%	National Park
Daniels Brook, Shepody Mtn	1978	Sept 2011	77	90-165m	6.9	95%	Shepody Mountain, private
Hamilton Creek West, Shepody Mtn	2011	Oct 2011	2	220m	DNC	DNC	Shepody Mountain, NB Crown
NOVA SCOTIA							
Eatonville Brook, Cape Chignecto	2006	July 2011	200+	51-20m	6.7-7.4	56%	Cape Chignecto Provincial Park
Lake Brook, Folly Lake, Cobequid Mtns		May, July, Aug 2011	120+	241-200m	5.7-6.0	38%	Private
Carter's Lake Brook tributary, Folly Lake, Cobequid Mtns		May, July 2011	30	240-230m	5.7	30%	Private
West River Lake Brook, Guysborough Co	2011	Nov, Dec 2011	500+	155-128m	6.2-6.6	100%	NS Crown
Melopseketch brooklet, Guysborough Co	2011	Dec 2011	1	149m	5.6	100%	Crown
Embree's Brook tributary, Port Hawksbury	2008	Sept 2011	12	74-61m	7.1	10%	Crown?
Gray's Hollow Brook, North River, Cape Breton	2008	Sept 2011	23	63m	7.5	25%	Pollett's Cove-Aspy Bay Wilderness Area
A tributary of Beaver Brook in the Gerrish Valley, Colchester Co		2012	100+	149-202m	6.9	45%	Private
QUÉBEC							
Rivière Noire, Montmorency Co	1990	Aug 2012	12	723m-717m	6.3	20%	Managed forest, Laval University

Table 3. Brooks that were searched without results for *Peltigera hydrothyria* in 2011 and 2012 by Frances Anderson, Tom Neily and David Richardson in Nova Scotia and by Frances Anderson and Ben Phillips in New Brunswick. Many of the brooks have no name, so the nearest identifiable place appears in column 1. The percentage of the brook searched depended in part on the suitability of habitat conditions in and around the brook. DNC = data not collected. UTM = NAD83.

TABLE AVAILABLE UPON REQUEST FROM THE COSEWIC SECRETARIAT.

In New Brunswick, searches in 2011 identified only one additional site for *P. hydrothyria,* in Hamilton Creek West, approximately 1 km from Daniels Brook where Gowan found it in 1978 (Table 3 and Table 4). In 2013, searches also led to the discovery of a second site in Fundy National Park. Stephen Clayden and colleagues did not detect any *P. hydrothyria* during earlier general lichen surveys in the province.

Table 4. Streams in the Maritime provinces and Québec that were searched by Stephen Clayden without finding *Peltigera hydrothyria*.

TABLE AVAILABLE UPON REQUEST FROM THE COSEWIC SECRETARIAT.

Table 5. The results of the Threats Classification and Assessment Calculator exercise for *P. hydrothyria*.

Species or Ecosystem Scientific Name		*Peltigera hydrothyria*	
2012-09-17			
David Richardson and Frances Anderson			
		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	2	2
C	Medium	1	1
D	Low	4	4
Calculated Overall Threat Impact:		Very High	Very High
Assigned Overall Threat Impact:		**A = Very High**	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
3	Energy production & mining	D	Low	Small (1-10%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
3.1	Oil & gas drilling	C	Medium	Restricted (11-30%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Fracking, impoundments for fracking effluent; exploration for natural gas

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.2	Mining & quarrying	D	Low	Small (1-10%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Gold mining near Guysborough site
3.3	Renewable energy	D	Low	Restricted (11-30%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	50 Wind turbines slated for construction in Cobequids
4	Transportation & service corridors	D	Low	Small (1-10%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Additional transportation related to mining and gas production
5	Biological resource use	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	
5.3	Logging & wood harvesting	B	High	Large (31-70%)	Extreme - Serious (31-100%)	High (Continuing)	Logging and biomass harvesting in Cobequids (Gerrish valley, Eatonville and Folly Lake), Guysborough and Daniels Brook NB.
6	Human intrusions & disturbance	D	Low	Restricted (11-30%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
6.1	Recreational activities	D	Low	Restricted (11-30%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Siltation in streams as a result of ATV use
7	Natural system modifications	C	Medium	Restricted (11-30%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
7.2	Dams & water management / use	C	Medium	Restricted (11-30%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	If fracking exploration successful, large amounts of water required in processing, which may affect water table, and construction of water impoundments may be needed
9	Pollution	D	Low	Large (31-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
9.5	Air-borne pollutants	D	Low	Large (31-70%)	Slight (1-10%)	Moderate – Insignificant / Negligible	Continuing acid rain may exceed the buffering capacity of the watershed, so the stream pH may drop and negatively affect the lichen. The Port Hawksbury site may also be affected as a result of commissioning of the new biomass plant and restarting of the paper mill.
11	Climate change & severe weather	B	High	Pervasive (71-100%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts	B	High	Pervasive (71-100%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Summer warming trends as a result of climate change
11.4	Storms & flooding	B	High	Pervasive (71-100%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Increased storm events and winter rain leading to scouring of the stream bed and rocks, resulting in removal of the lichen

Table 6. Details of the threats faced by *Peltigera hydrothyria* at the various occurrences in Québec, New Brunswick and Nova Scotia.

Threat	Fundy NP, NB	Daniels Brook, Shepody Mtn. New Brunswick	Eatonville Brook, Cape Chignecto, Nova Scotia	Carter's Lake Brook, Cobequid Mountains, Nova Scotia	Embree's Brook, Port Hawkesbury, Nova Scotia	Gray's Hollow Brook, Cape Breton, Nova Scotia	West River Lake Brook, Guysborough Co, Nova Scotia	Tributary of Beaver Brook, Gerrish Valley, Colchester Co.	Rivière Noire, Québec
Threat Category: Habitat Loss or Degradation									
Commercial forestry (including biomass harvesting)	None	Moderate Some former and current activity by landowner(s)	Provincial Park. Activity on perimeter may affect water levels and quality	Moderate to high There is no current activity but there was a recent clear-cut adjacent to a tributary flowing into this stream	Moderate to high Terrain and forest type suitable for biomass only. Biomass facility nearby	Moderate Brook comes out of Provincial Wilderness Area Crown land protected, but private owner may log	High Currently clear-cutting less than 1km away. Crown lease	Moderate to high. Possible effects of forestry upstream on stream quality	Low at site. Already harvested 10 years ago. Upstream possible
Wind turbines, mineral extraction, including hyrdofracturing, affecting water levels or quality	Low	Low	Moderate to high Exploratory leases have been granted in area	High Increase in turbine numbers and exploratory leases have been granted in area	Low No known deposits in area	Low	Low to moderate Gold being mined within 20km	Low	Low Forêt Montmorency managed by Laval U for forestry
Threat Category: Changes in Ecological Dynamics or Natural Processes									
Increased incidence of storms	Moderate Higher water levels during normally low periods could affect reproductive potential	Moderate Increasing frequency of intense fall & early summer rainstorms with resultant increased scouring	Moderate Higher water levels during normally low periods could affect reproductive potential	Moderate Higher water levels during normally low periods could affect reproductive potential	Moderate Higher water levels during normally low periods could affect reproductive potential and increase siltation	Moderate Higher water levels during normally low periods could affect reproductive potential	Moderate Higher water levels during normally low periods could affect reproductive potential and increase siltation	Moderate Higher water levels during normally low periods could affect reproductive potential	Moderate Higher water levels during normally low periods could affect reproductive potential

Threat	Fundy NP, NB	Daniels Brook, Shepody Mtn. New Brunswick	Eatonville Brook, Cape Chignecto, Nova Scotia	Carter's Lake Brook, Cobequid Mountains, Nova Scotia	Embree's Brook, Port Hawkesbury, Nova Scotia	Gray's Hollow Brook, Cape Breton, Nova Scotia	West River Lake Brook, Guysborough Co, Nova Scotia	Tributary of Beaver Brook, Gerrish Valley, Colchester Co.	Rivière Noire, Québec
Climate change (temperature rise)	Moderate If warmer temperatures overwhelm projected increases in precipitation, prolonged dry periods and/or extended warm water temperatures and further reductions in marine advection fog would likely kill the lichen	High If warmer temperatures overwhelm projected increases in precipitation causing low water levels and prolonged dry periods	High If warmer temperatures overwhelm projected increases in precipitation, prolonged dry periods and/or extended warm water temperatures would likely kill the lichen	Moderate If warmer temperatures overwhelm projected increases in precipitation, prolonged dry periods and/or extended warm water temperatures would likely kill the lichen	Moderate If warmer temperatures overwhelm projected increases in precipitation causing low water levels and prolonged dry periods	Moderate If warmer temperatures overwhelm projected increases in precipitation, prolonged dry periods and/or extended warm water temperatures would likely kill the lichen	High If warmer temperatures overwhelm projected increases in precipitation, prolonged dry periods and/or extended warm water temperatures would likely kill the lichen	Moderate If warmer temperatures overwhelm projected increases in precipitation, prolonged dry periods and/or extended warm water temperatures would likely kill the lichen	Moderate If warmer temperatures overwhelm projected increases in precipitation, prolonged dry periods and/or extended warm water temperatures would likely kill the lichen
Threat Category: Disturbance or Harm									
Road building, changing runoff and increasing siltation	Low	Low	Low	Moderate	Moderate	Low	High Existing road causes siltation. Currently little used, about to change	Low, site in a steep valley	Low
ATV	Low	Moderate A few old logging roads exist; not a highly populated area	Moderate ATV use supposed to be prohibited but rogue users persist	Moderate A few old logging roads exist; not a highly populated area	Moderate to high Nearby power line cut is currently used by ATVs	Moderate Steep, inaccessible upstream ravines may deter much ATV activity	Moderate to high Much use of nearby logging roads for ATV travel	Low, site in a steep valley	Not known Existing roads well maintained, off-road use not visible
Threat Category: Pollution									
Airborne pollutants, especially acid rain	Moderate	Moderate	Moderate	Moderate	Moderate Nearby pollution sources (paper mill, biomass generator) but buffering capacity of brook high and wind patterns not favourable	Low Lies outside main affected areas; buffering capacity of brook high	Moderate Lies outside main affected areas; buffering capacity of brook moderate	Moderate	Not known

In Québec, Claude Roy discovered a population of *P. hydrothyria* in 1990 at a single occurrence in la Rivière Noire in the reserve of la Forêt Montmorency. Despite further searches for this taxon in many other similar streams in new localities in Québec, he did not find it (Claude Roy pers. comm. 2011). The site was revisited in 2011 and a specimen was collected by Frances Anderson for a molecular study (Lendemer & Anderson 2012). Another visit was made by members of the Lichens and Mosses Subcommittee of COSEWIC in August 2012 to search in Rivière Noire and Rivière Montmorency. The water level was very low and ten more thalli were found at and downstream from the original site. However, none were found below the waterfall and in the nearby Rivière Montmorency, so *P. hydrothyria* appears not to be common in Rivière Noire or in the general area. During the 2012 Tuckerman Workshop in the Parc de la Gaspésie, Gaspé Peninsula, Québec, Frances Anderson and Stephen Clayden searched eight streams in the park without finding *P. hydrothyria*. All but two had no bryophytes on the rocks, which suggests heavy seasonal scouring. Of the two streams with bryophytes, one was so steep as to be largely inaccessible, and bryophytes were covered with large amounts of algae in the other.

One obvious question is why there is an isolated occurrence of *P. hydrothyria* north of Québec City, but none in the area intervening between this and the occurrences in the Maritime Provinces. The answer seems to be an unsuitable climate in combination with the lack of streams with suitable habitat and water quality. The occurrences of *P. hydrothyria* are all in or near areas with a perhumid climate (Clayden *et al.* 2011) (see Habitat section below and Figure 3). The area of the falls on the Rivière Noire in Québec has several other widely disjunct lichens, including *Gyalideopsis piceicola* and *Pilophorus cereolus*, which are similarly dependent on the exceptionally humid local climate.

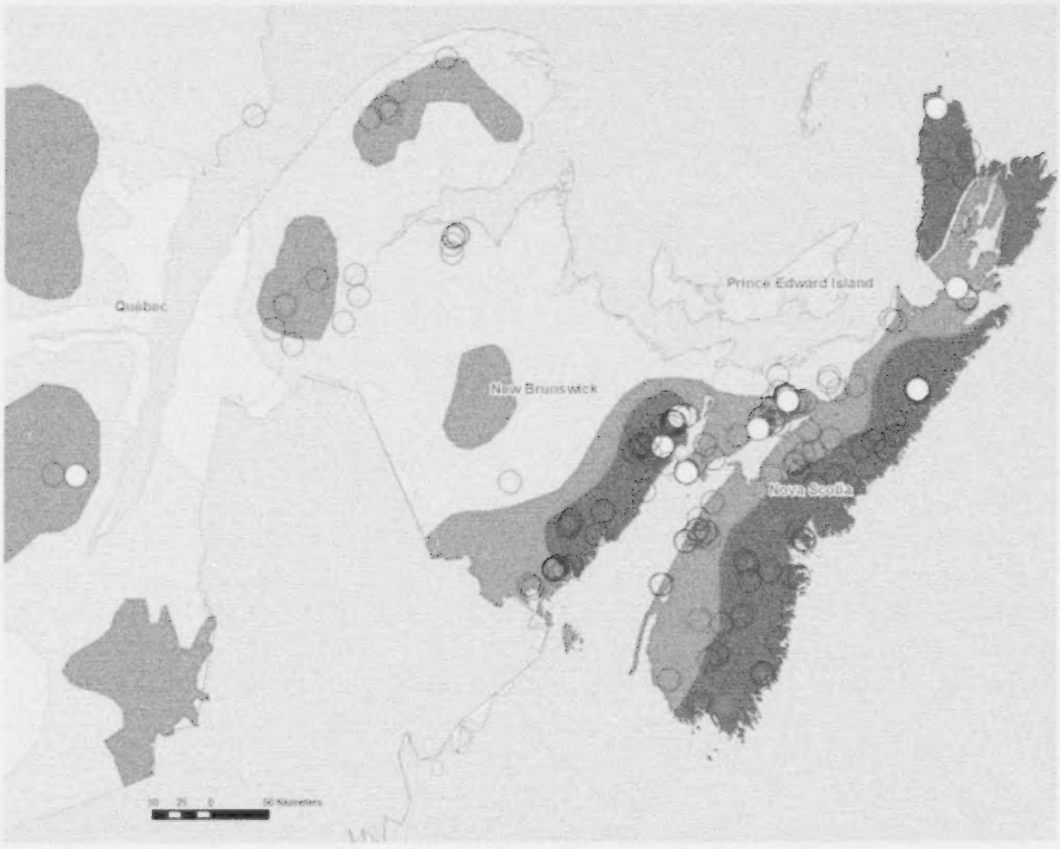

Figure 3. The distribution of *P. hydrothyria* in Canada. The pale yellow circles mark the occurrences where the lichen has been found, and the open circles show where streams have been searched unsuccessfully. Note that the occurrence is strongly correlated with a high moisture index, indicating the importance of high habitat humidity to this lichen. Humidity sectors are shown in the Atlantic Maritime Ecozone. Perhumid climate areas (moisture index of 100) are shown in dark green and very humid climates in medium green (index 80-99) (see Clayden 2010) (map R. Cameron).

To help understand the distribution of *P. hydrothyria,* it is relevant to consider other lichens found in the Appalachian mountains which also reach the northeastern limits of their North American ranges in eastern Canada, for example, the epiphytic species *Erioderma mollissimum, Everniastrum catawbiense, Heterodermia squamulosa, Hypotrachyna afrorevoluta, H. revoluta, Pseudevernia cladonia, Punctelia appalachensis*, and *Usnea merrillii*. In Atlantic Canada, all of these species are restricted to near-coastal or montane areas with high precipitation. However, none of them has been found in the central highlands of New Brunswick (or any location in this province more than c. 35 km inland from the Bay of Fundy (Stephen Clayden pers. comm.). This is despite intensive survey efforts by Stephen Clayden and Steven Selva. These findings indicate that there is a group of primarily Appalachian species, very probably including *P. hydrothyria*, which do not occur in the upland/montane areas of western and northern New Brunswick. It should also be noted that in neighbouring Maine, the only known occurrences of *P. hydrothyria* are in the western part of the state (Oxford County) adjoining New Hampshire (Hinds & Hinds 1998). It has not been found in intensive surveys of the lichens of the Katahdin area (Hinds *et al.* 2009). Thus even a future extended search for *P. hydrothyria* is unlikely to increase significantly the number of occurrences much above the currently known ten.

HABITAT

Habitat Requirements

In eastern North America *P. hydrothyria* occurs in mineral-enriched streams, which typically have a summer pH of above 6, where there are small waterfalls, exposed boulders and/or sinuous stream configurations that create quiet backwaters where the lichen can grow outside the main water flow (Figure 4). Recently, an exception was found to this at Dickson Brook in Fundy National Park in which there were individuals growing in turbulent water where the current seems to influence the lichen; this causes it to grow length-wise rather than in the typical radiating fashion (Ben Phillips pers. comm.). Typically, *P. hydrothyria* grows attached to rock below or at water level in clear, cool, streams that are partially shaded (Figure 5).

Figure 4. The habitat of *Peltigera hydrothyria* at Black Brook in Fundy National Park, New Brunswick. The lichen occurs on the stream margins, behind boulders and in backwaters (Photo: F. Anderson).

Figure 5. *Peltigera hydrothyria* growing below water level on a stream bed of Carter's Lake Brook in dappled sunlight in clear water. The lichen is in the centre as well as in the upper and middle right (photo: D. Richardson).

Peltigera hydrothyria is found in streams where silt or sediment is absent and where there is little to no green filamentous algae. Clear water is a constant feature although there may occasionally be a visible iron stain on the rocks. Bryophyte cover in the streams varies from scattered to abundant.

Humidity is a key component of the habitat, particularly where thalli seasonally remain partially above water. During the summer of 2011, all but one of the eastern Canadian sites of *P. hydrothyria* had some or most of the thalli partially to 95% exposed. The thalli were kept moist by the high humidity and proximity to the stream water and to wet bryophytes. The occurrences of *P. hydrothyria* are all in or adjacent to areas with a perhumid climate (Figure 3, Clayden *et al.* 2011). 'Perhumid' refers to a climate where precipitation greatly exceeds evaporation and plant transpiration, resulting in year-round wetness. Perhumid areas may undergo short periods when water loss exceeds water gains, but abundant rain, snow or meltwater in flanking periods makes up for these shortfalls (Clayden *et al.* 2011). Perhumid climates occur in island-like areas of high elevation along the Appalachian Mountain chain and more widely in coastal eastern Canada and a small area of Québec (Figure 3).

In the past it has been stated that *P. hydrothyria* occurs in mountain streams (Hale 1969, Dennis 1981, Brodo *et al.* 2001), but the elevation of *P. hydrothryia* in eastern Canada ranges from 10-250m above sea level in Nova Scotia. The only occurrence in Québec is at 723m. The climate, vegetation cover and water quality of streams are more likely determinants of suitable conditions than elevation (Davis *et al.* 2003). There are no data on the annual maximum and minimum water temperatures for streams in which *P. hydrothyria* occurs in eastern Canada. Flow direction, water depth and rate of descent are potential temperature-affecting variables that may determine a stream's suitability. Partial shade over the stream helps keep humidity high and temperature low during the summer months when water levels are low and the lichen is exposed, without completely excluding light.

Stream pH typically varies throughout the year, particularly in eastern Canada. Runoff after rain, snow events and spring melt often increase acidity in watercourses (Clair *et al.* 2007, Agren *et al.* 2010). Stream pH is usually highest in summer. Habitat data collected in 2011 suggest that *P. hydrothyria* occurs in streams where the summer seasonal pH is typically between 6.0 and 7.0 (Table 2). No information exists on minimum seasonal pH in the streams where *P. hydrothyria* occurs, but the lowest pH measured in the 2011 surveys in Canada was 5.6 in a stream visited in December (Table 2).

Peltigera hydrothyria thalli are nearly always found attached directly to rock substrata, though at one site in Guysborough County, Nova Scotia, thalli were also found attached to a submerged branch. In all but two of the known eastern Canadian streams where *P. hydrothyria* has been found, bedrock ledges and small boulders create small waterfalls near where the thalli occur. All the streams have rocks of various sizes which create protective eddies and backwaters. It is possible that good aeration of the water may be important but no studies have been done on this aspect. At the Guysborough County site, there is no visible bedrock, and the stream contains more humus than in any of the other streams.

Peltigera hydrothyria may be able to survive short periods of drying. In eastern Canada in July and August 2011, all sites except the one in Québec had some exposed thalli. In most cases, the upper portions of the thallus were exposed with the base remaining either submerged or amongst densely growing wet bryophytes. Seasonal stream level fluctuations are clearly tolerated by *P. hydrothyria*, even though the literature states that it cannot survive total desiccation as other lichens do (Hale 1969, Brodo *et al.* 2001, Davis *et al.* 2003). No data exist on the length of time that a thallus of *P. hydrothyria* can survive dry or with only a portion wet. At one site, Shepody Mountain, New Brunswick (Figure 6), there is little water flow but the lichen occurs in a deep ravine among bryophytes and this probably maintains high humidity which keeps the thalli moist during dry seasons. In the USA at Cascade, Wantasquit Mountain, near Brattleboro, Vermont, a stream was reported to dry for part of the year in mid-summer but the lichen occurred in abundance (Russell 1853).

Figure 6. *Peltigera hydrothyria* site at Daniels Brook, Shepody Mountain, New Brunswick, an atypical habitat for this lichen in Atlantic Canada (photo: F. Anderson).

Another important requirement for cyanolichens such as *P. hydrothyria* is a pollution-free environment (Richardson 1992). Nitrogen fixation is essential for their survival and it is disrupted by acid rain (Gilbert 1986, Cameron & Richardson 2006), which causes a reduction in pH and depletes or inhibits the uptake of nutrients such as phosphate which are essential for nitrogen fixation. In Nova Scotia, New Brunswick and Québec much of the geology consists of acidic rocks, and stream water is further acidified by transboundary acid rain. Streams in areas where the rock is mineralized have water of a suitable pH, typically 6-7, and also have the ability to buffer the pH reduction caused by acid rain. Only such streams are likely to support *P. hydrothyria*.

Habitat Trends

Peltigera hydrothyria is one of the lichens for which the number of extant occurrences has declined in New England, primarily due to a combination of air pollution and habitat destruction (Hinds & Hinds 2007).

No data exist to document historical changes to stream habitats in eastern Canada. The few known sites of *P. hydrothyria,* despite extensive searches, suggest that it occupies a very narrow niche. The requirements include silt-free water of appropriate pH and temperature, but there may be other not-yet recognized factors that affect the establishment and success of *P. hydrothyria*. In terms of habitat trends, forestry activity, mining and development have all made incursions into undisturbed woodlands and the frequency of these disturbances is increasing (see Threats section below).

BIOLOGY

Life Cycle and Reproduction

Sexual reproductive structures (apothecia) are common in all but small thalli of *P. hydrothyria*. Some thalli grow several centimetres below the water level even during the drier summer months, and it is not known if asci in the apothecia of these thalli are able to discharge spores under water. In this context it is interesting that three thalli of *P. hydrothyria* collected more than 5cm below the water surface at the end of the very dry summer of 2012 from the Rivière Noire in Québec all lacked apothecia (Richardson and Roy pers. comm. 2012). It is not known if exposure to air is required to stimulate fruit body formation or exactly how germinating ascospores or thallus fragments become attached to rocks below the water surface (as observed in Québec). The generation time for lichens varies from ten years in rapidly colonizing lichens such as *Xanthoria parietina* to more 17 years for old-growth forest lichens such as *Lobaria pulmonaria* (Scheidegger & Goward 2002, Larsson & Gauslaa 2010).

At most sites examined in the summer of 2011, parts of some thalli, particularly the lobe margins where apothecia occur, were found above the water level. The only study of ascospores in *P. hydrothyria* showed that spore discharge occurred into the air within two hours when apothecia were suspended over soil extract agar. The ascospores that fell onto the agar surface germinated within 16 hours. The spores germinated better when in groups rather than when isolated. The initial growth was stimulated by bacterial contamination but attempts to culture the fungus *in vitro* failed (Kele 1964, Ahmadjian 1989). Spore discharge and reproduction probably occurs in late summer and early autumn. At that time, water levels are generally low and the thalli are at or above water level so that the ascospores can be ejected into the air (Glime 1984). When the spores that are ejected land on a rock in a stream with appropriate water quality and habitat, it is presumed that, as in other cyanolichens, they germinate and are attracted to grow toward any nearby cyanobacteria. If the latter are compatible, they become enveloped by the fungal strands and eventually grow to become a visible thallus (Honegger 2008).

There are no specialized vegetative propagules. Under favourable conditions thalli of *P. hydrothyria* can develop into large colonies, 10cm or more in diameter. Loss of lobes from these colonies, essentially fragmentation, is probably common. If these lobes are swept downstream onto surfaces where the fragment can take hold and become reattached, they could be a means of reproduction. No studies to confirm this have been completed.

Herbivory and Predation

A wide range of small invertebrates are known to be associated with and feed on lichens, including *Thysanurans, Collembolans, Psocopterans*, *Lepidopteran* larvae, orbatid mites and gastropods (Seaward 2008). Nothing is known about invertebrates associated with or which might eat *P. hydrothyria*.

Physiology and Adaptability

Peltigera hydrothyria is part of a group of lichens known as cyanolichens because the photosynthetic partner is a cyanobacterium. The cyanobacteria provide carbohydrates through photosynthesis to the fungal partner and the presence of heterocysts indicates that the contained photobiont can fix atmospheric nitrogen and transfer amino acids as well (Jacobs & Ahmadjian 1973). Phosphorus plays a key role in the process of nitrogen fixation, and phosphate uptake is inhibited by low pH (Nash 2008). Aquatic cyanolichens like *Peltigera hydrothyria* are likely to be very sensitive to acidification of stream water by air pollution or acid rain.

Prior to separation into two species, *P. hydrothyria* was thought to contain the cyanobacterium *Nostoc*. Casmatta *et al.* (2006) discovered true branching in the cyanobacterium and other features that identified the photobiont as *Capsosira lowei*. Very little is known about the occurrence or abundance of this alga.

Like other cyanobacteria-containing lichens, *P. hydrothyria* needs liquid water in order to photosynthesize (Lange *et al.* 1986) but water is more available to this lichen than to most other cyanolichens as it grows at or below water level for most of the year. Silt-free water appears to be a constant characteristic of sites where *P. hydrothyria* exists; this may be because siltation on the thallus surface reduces or prevents photosynthesis.

Experimental studies were carried out on the closely related species *P. gowardii*. These studies showed that water temperature is very important. If illuminated thalli were maintained in water at 5°C, there was little change in weight or photosynthetic capacity for periods of long as 400 days. However, at higher water temperatures a decline in both parameters was found, and at 18°C this was evident after just 30 days. At higher temperatures the decline in net photosynthesis was due to high dark respiration rates. There is a time-tolerance relationship so that 100 days is tolerated at 11°C, 60 days at 15°C, and only 30 days at 18°C (Davis *et al.* 2003). It is not known if *P. hydrothyria* has the same tolerances. In Tennessee, the mean water temperature in May of streams where *P. hydrothyria* occurred was 9°C (range, 3–18°C) (Dennis *et al.* 1981). Water temperatures of colonized streams in Nova Scotia and New Brunswick, recorded during daylight hours in July and August 2011, ranged from 12-18°C, but there are no data on the diurnal minimum.

In laboratory studies on the related *P. gowardii*, it was found that nitrate levels at or above 5mM led to a decline in photosynthesis and weight of the thallus, but at 2mM nitrate, an increase in photosynthesis thallus weight was observed. This was greater than in the absence of nitrate, so low levels of nitrate appear to be beneficial (Davis *et al.* 2000). Clear-cutting of forests increases the nitrate content in nearby streams (Goudie 2006, Tremblay *et al.* 2009). This and the nitrate component of acid rain have been hypothesized to increase nitrate levels in stream waters sufficiently to negatively affect *P. gowardii* populations. Agricultural runoff and effluent from septic tanks are also threats (Davis *et al.* 2000). The threats from clear-cutting, acid rain, etc., probably apply to populations of *P. hydrothyria* in eastern North America.

Dispersal and Migration

Lichen ascospores provide a means for dispersal over longer distances but success is dependent upon spores landing in a stream with requisite pH, water temperature, light gradient and aeration (see Habitat section above and Table 2) and the presence of compatible cyanobacteria. This is likely a rare event made more difficult by the fact that in Canada *P. hydrothyria* occurs in streams that have small waterfalls and are often sinuous, well shaded, and frequently within narrow valleys where wind speeds are limited. Thus wind is not likely to entrain spores shot off close to the stream water level. It is not known if spores can survive immersion in water and be washed downstream, then germinate on a rock surface and give rise to a new thallus.

Over long time periods, however, ascospores are probably responsible for long-distance dispersal of the lichen and account for its current distribution. A recent study using molecular methods suggested that lichens can frequently cross distances of at least several kilometres but are primarily limited by the availability of habitat rather than spore dispersal (Lattman *et al.* 2009).

There are no specialized vegetative propagules. However, the fragmentation of lobes from large thalli of *P. hydrothyria* may occur and if they become reattached, they could be a means of downstream dispersal and migration of the species within a watershed. Using highly visible red glitter as a dispersal mimic for small seeds of aquatic plants, Levine (2001) found that the glitter could move up to 4.5 km downstream.

Movement upstream is critical to the long-term persistence of riverine populations (Levine 2001). It is possible that fragments of *P. hydrothyria* are dispersed upstream on the feet of birds or even mammals wandering through the stream. Lichen fragments have been found on birds' feet but very few birds have been examined (Bailey & James 1979).

Interspecific Interactions

Only a few lichens in eastern North America can withstand periodic or prolonged submersion in fresh water and hence compete for habitat with *P. hydrothyria*. Macrolichens include *Placynthium flabellosum, Ephebe lanata, Leptogium rivulare* and *Dermatocarpon luridum*. In addition, a number of crustose species, especially *Verrucaria* spp., also occur in this habitat.

A variety of bryophytes such as *Fontinalis dalecarlica, Eurynchium riparioides,* and *Bracythecium* spp., grow in association with, or in the same habitat as, *P. hydrothyria*. Competition with some of them is likely although no detailed study or list of associated bryophytes has yet been made. At the Québec occurrence, the aquatic moss *Fontinalis dalecarlica* is abundant, while other bryophytes, notably *Scapania undulata, Marchantia polymorpha* and *Racomitrium aciculare* are found on rocks along the riverside (Claude Roy pers. comm. 2012; Faubert 2007). At Cape Chignecto Provincial Park, Nova Scotia, when water levels dropped in part of the stream, bryophyte density increased and when the site was visited five years later, the *P. hydrothyria* had disappeared as a result of the competition (Frances Anderson pers. comm. 2011). However, at most sites it appears that a certain density of bryophytes is needed to help to retain the moisture needed to prevent drying of thalli that grow at or near the surface during the low water levels observed during the summer (Anderson pers. comm. 2011).

Lichens can be attacked by lichenicolous fungi which may reduce growth and reproduction. To date, no such fungi have been identified on *P. hydrothyria* although members of the genus *Peltigera* which colonize terricolous habitats are well known to harbour a range of lichenicolous fungi (Hawksworth 1983).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

All sites in eastern Canada where *P. hydrothyria* has been collected or reported in the literature were visited in 2011 and 2012 to verify the lichen's continued existence. Prior to the present report, data have seldom included more than site details or co-occurring lichens. The goal of these visits was to assess the population of *P. hydrothryia* at each site and record habitat data including stream dimensions, streamside flora and water quality. The latter was gathered using field monitors that measured pH, water temperature, dissolved oxygen, conductivity, and water flow. A water sample was also collected for subsequent analysis at the Nova Scotia Department of Agriculture Laboratory, Truro. In addition, visits were made to as many nearby streams as possible to look for new occurrences (see Table 3).

Abundance

Historical records of *P. hydrothyria* have not included the number of thalli present at each site. The surveys carried out for this status report revealed that thallus abundance varies greatly in the ten occurrences and seven locations (Table 2, see discussion below in Threats section). The locations were respectively estimated to have 12 to 501 mature individuals (colonies) of *P. hydrothyria* present (Tables 1 and 2). Thus the total estimated population is 1,282 mature individuals (colonies). Further surveys may discover a few more sites where this lichen occurs, but it is doubtful whether the total population in Canada will exceed 2,000 individuals (colonies), taking into account the many streams where *P. hydrothyria* was searched for but not found. At some sites there were only a small number of thalli, while in others almost every rock in up to 5m stretches of a stream was colonized. In such areas it is difficult to determine where one thallus ends and the next begins. In spite of this challenge, more than 100 colonies were enumerated at a few sites (Table 1). The fact that some of the thalli are submerged also complicates the visual assessment (Figure 5).

Fluctuations and Trends

There are no historical records in eastern Canada for *P. hydrothyria* before 1978, and the occurrences found since then were only visited again in 2011, so there is insufficient documentation to assess fluctuations in the population of this lichen. The trend for populations in Nova Scotia will likely be downward due to the threats described in the Threats Section of this report (see below).

Peltigera hydrothyria is one of some 40 lichens, of which the majority are cyanolichens, that have exhibited decreases in three or more New England states over the past 100 years; habitat loss and past and prevailing air pollution are the most likely causes of this decrease (Hinds & Hinds 2007, p. 47).

Rescue Effect

The nearest source for *P. hydrothyria* is in western Maine (Hinds & Hinds 2007). Thus, there is the possibility of rescue effect for *P. hydrothyria* from the United States but the distances involved are large and the species is becoming increasingly rare in New England.

THREATS AND LIMITING FACTORS

Both historical and recent searches for *P. hydrothyria* have revealed that there are 13 current sites where this lichen occurs, which comprise 10 occurrences and seven locations (Table 1). A location is defined as a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present (COSEWIC, 2013).

The most serious potential threats to *P. hydrothyria* are changes in water quality and quantity associated with industrial activity, road building, or removal of trees adjacent to the stream habitats of the lichen. Other threats to the lichen include hydrofracturing, climate change, and air pollution.

Siltation and Decreased Water Quality

Clear, cool, silt-free water and a humid environment appear to be crucial to *P. hydrothyria*'s capacity to thrive (see Habitat Requirements and Physiology and Adaptability, above). Siltation of the lichen's stream habitat is a major concern (Gilbert and Giavarina 1997). A location near Cape Chignecto (Figure 8) appears to have been extirpated due to siltation. It is not known how short-term siltation events affect the survival of *P. hydrothyria*, but repeated events can coat the lobe surfaces, preventing photosynthesis. Silt can also cover potential establishment surfaces.

Siltation is associated with tree removal near waterways and improperly located, or maintained, culverts. Road construction can concentrate water flow and create increases in siltation (Cameron 2006). An increase in road traffic due to industrial activity (e.g. forestry, mining, hydrofracturing, wind power) increases the risk of siltation events. For example, the cause of a clearly visible siltation event at Eatonville Brook, Cape Chignecto in Nova Scotia (Figure 8) was upstream forestry operations just outside the provincial park followed by heavy rain. Within a year, *P. hydrothyria* had disappeared from the site downstream of where the silt entered the park, although the lichen was still present at other sites that were not silt-affected, within this occurrence.

Figure 7. A recent clear-cut adjacent to Carter's Lake Brook tributary that is colonized by *Peltigera hydrothyria* in the Cobequid Mountains (photo D. Richardson).

Figure 8. Siltation following heavy rain observed in Eatonville Brook, Cape Chignecto, which originated from forestry activity outside the park. This silt was brought in by an inflowing stream (photo: F. Anderson).

Also, removal of trees growing near stream banks exposes streams to the possibility of erosion and runoff. Winter snow and ice accumulation may increase near and around streams where tree removal has occurred. This can potentially lead to ice scouring during the spring melt, which could remove *P. hydrothyria* colonies from their substrate. Increased exposure to wind and light in harvested areas can also reduce humidity levels on and around rocks in and on the margins of streams so that during months with low water levels, thalli may be exposed and dry beyond their tolerance limits. It is not known if riparian harvesting restrictions, where they exist, are sufficient to prevent these changes. Riparian buffers are required on public and private land In New Brunswick and in Nova Scotia. The width varies depending on slope but generally is 30 in New Brunswick and 20m in Nova Scotia (Nova Scotia, 2002, Lee *et al.* 2004, Agriculture & Agri-Food Canada 2013). It is not known if riparian harvesting restrictions are sufficient to prevent these changes. The edge effects of increased temperature and decreased humidity on bryophytes, for instance, have been documented to occur up to 100m from a clear-cut edge (Baldwyn & Bradfield 2005, Hylander 2005, Hylander *et al.* 2002, Stewart & Mallick 2006).

Decrease in Water Quantity

The volume of water in the streams associated with *P. hydrothyria* is often quite small and the streams are shallow, usually < 0.5m deep. Changes to the hydrology of the watersheds, in addition to siltation, could impact this lichen. Clear-cut forest operations lead to changes in water-table levels that again could negatively affect the survival of *P. hydrothyria* (Likens *et al.* 1970, Dube *et al.* 1995).

Similarly, hydrofracturing activities have the potential to alter rock stability and groundwater patterns (Entrekin *et al.* 2011, Bundale 2012a). Impoundments may be built to divert water for use underground, potentially detracting water that could enter waterways (REFS). Effluent disposal could also be a problem for water quality, depending on where effluent is stored (REF). Hydrofracturing and related operations may affect water sources at some distance from the main activity. In Nova Scotia, mineral and gas exploration leases could potentially impact two *P. hydrothyria* occurrences. One is in the Cobequid Mountains, the other is near Cape Chignecto (Figure 9). There is no hydrofracturing yet permitted in Québec, but both NS and NB are allowing exploration leases.

Climate Change

Regional trends in seasonal temperatures for Atlantic Canada show an overall warming of 0.3°C over the last fifty years, with summers showing the greatest increase of 0.8°C. Summer temperatures are predicted increase by 2 to 4°C by 2050 and by 1.5 and 6°C in winter. Precipitation is also expected to increase, with greater seasonal and yearly variations. Drier conditions may occur in inland regions as higher summer temperatures will likely cause increased evaporation (Vasseur & Catto 2008, Clayden 2010). Analyses presented at the recent 'Climate Change: Getting Ready' conference in Halifax indicate that increases in temperature over the last five to ten years in Nova Scotia have exceeded the higher of the model predictions (D. Forbes pers. comm. 2012). In addition, analyses of fog frequency along the Atlantic coast of Nova Scotia and the Bay of Fundy predict that the decline over the past several decades will continue (Beauchamp *et al.* 1998, Muraca *et al.* 2001, Percy *et al.* 2005).

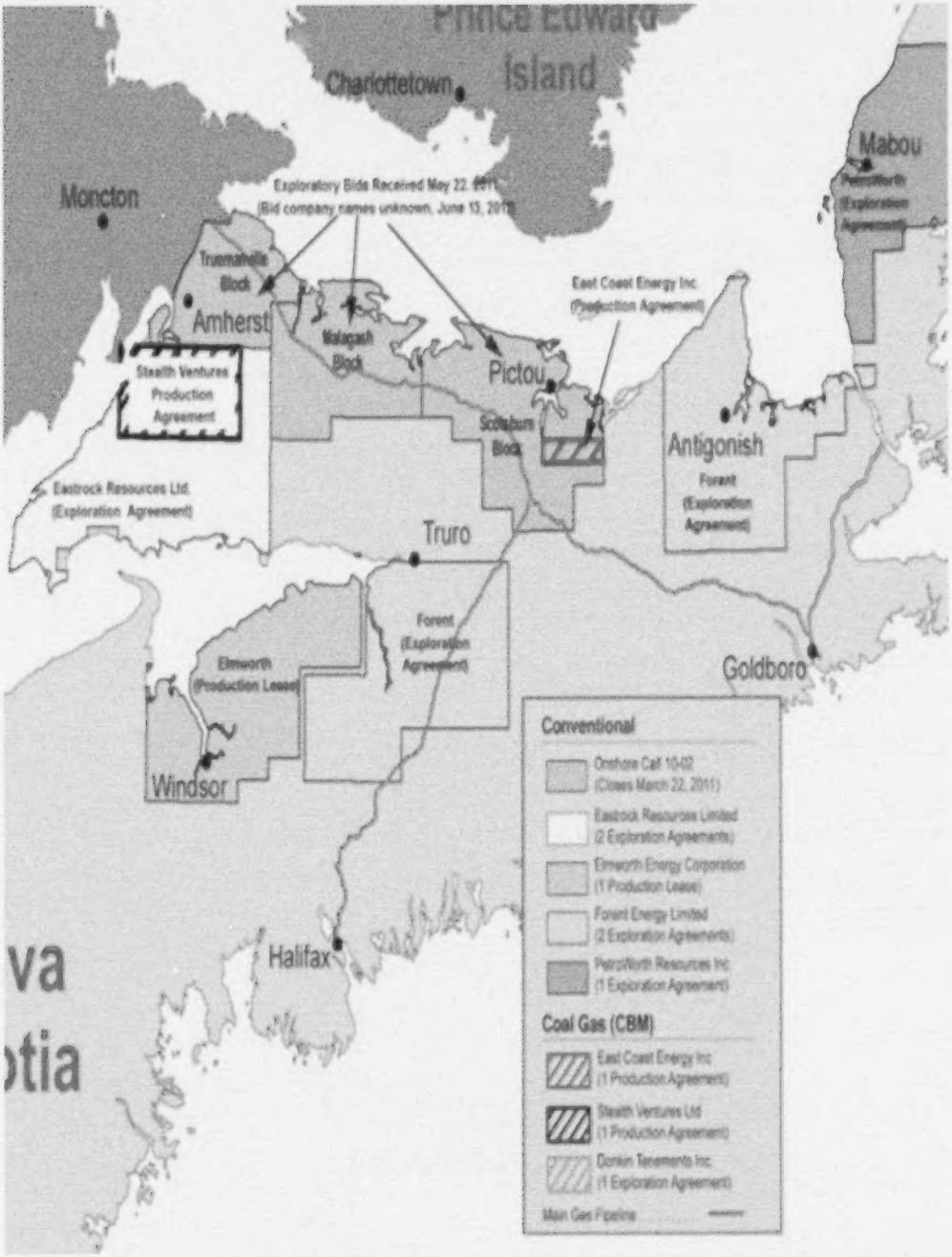

Figure 9. Proposed areas for hydrofracturing activities associated with shale gas extraction (Anon. 2011). Note that *Peltigera hydrothyria* occurs in two areas: the yellow area, labelled Eastrock Resources Ltd., includes the Cape Chignecto occurrence and the purple area near Truro is close to the Colchester Co. occurrences

Taken together, the above climate change features may lead to less water flow at more inland occurrences and a reduction in humidity along the stream margins. This could prevent populations of *P. hydrothyria,* which must be moist for extended periods, from photosynthesizing and growing.

Air Pollution

Cyanolichens are extremely sensitive to air pollution and acid rain (Richardson & Cameron 2004, Cameron & Richardson 2006). Transboundary air pollution is still affecting Atlantic Canada and may continue to alter water quality. The 2004 and 2011 Canadian Acid Deposition Science Assessment results indicated that total acid deposition has declined significantly in eastern North America (Burns *et al.* 2011). Despite these declines, large areas in southern New Brunswick and southern Nova Scotia will continue to receive acid rain as a result of transboundary air pollution (CCME 2004, 2011). Continued exposure to acid rain as well as acidity from forest harvesting may eventually exceed the buffering capacity of the watershed or substratum causing the water to become more acidic (Nieboer *et al.* 1984, Agren *et al.* 2010). This could prevent cyanolichens like *P. hydrothyria* from thriving. Very young thalli appear to be most sensitive. It is not yet known how much buffering capacity remains in the various streams where *P. hydrothyria* exists, so the impact of reduced, but continuing, acid rain is difficult to predict.

Threats vary at each location. The following gives details of the potential threats noted at each location, as they are defined in Table 1.

The main threat to the first location (Table 1), which includes the occurrences in New Brunswick and the one at Cape Chignecto, is climate change, especially a predicted reduction in fog (see above under Climate Change). The latter occurrence has been, and may in the future be affected by siltation from forestry or other activities outside the park.

Siltation resulting from forest harvest is also a concern. Upstream forestry operations just outside Cape Chignecto Provincial Park produced clearly visible siltation after rain in the stream (see Figure 8) where two sites for *P. hydrothyria* formerly existed (Anderson 2004-2007). One of those sites has disappeared. Glavich (2009) noted that the closely related species *P. aquatica* also required streams with little to no siltation. Siltation from roads and construction associated with the proposed expansion of wind turbines and biomass forestry operations in Nova Scotia is a major threat to streams.

The second location, Carter's Lake Brook in the Cobequid Mountains in Colchester County, NS, is threatened by construction related to an expansion of wind turbines (Table 1). An increase from 3 to 50 wind turbines has been proposed for the Cobequid Mountains. Construction and road-network building could lead to disturbance and enhanced siltation in the streams where *P. hydrothyria* grows (Alberstat 2012a). Nearby forestry activities could also be a threat as the sites are unprotected. There is a recent clear-cut close to the tributary of Carter's Lake Brook (Figure 7) and its impact on *P. hydrothyria* needs monitoring. This location is also threatened by climate change, particularly warmer summers that are anticipated in inland areas of Nova Scotia. Recent models suggest that the amount of summer precipitation in Nova Scotia will not change much, but there will be more drought due to increased evapotranspiration. Drought reduces water flow and therefore stream depth, which can lead to desiccation and death of the Eastern Waterfan. One very dry summer could have a large impact on the population of this lichen. The climate models suggest that in winter there will be more precipitation and a higher proportion of it will fall as rain. The increased water flow is likely to enhance scouring, which can remove the Eastern Waterfan from rocks on the margins and bottoms of streams.

The third location is Beaver Brook in the Gerrish Valley, near Economy Mountain also in Colchester County. As with location two, the main threat in the Gerrish Valley is forestry. The land surrounding this location is privately owned, much of it by Northern Pulp Ltd. The company has done some extensive clear-cutting in this watershed as well as herbiciding. In the longer term, climate change is also a threat.

The fourth and fifth locations (Table 1) are in Guysborough and Richmond counties, where the main threat is siltation as a result of forest removal and other aspects of human disturbance. Currently, forest harvesters in Nova Scotia are only required to leave a 20m buffer on each side of streams, 30m in New Brunswick. At the Guysborough occurrence, a logging road crosses over the stream where *P. hydrothyria* occurs. Cutting is already occurring throughout the neighbouring Liscomb Game Sanctuary area and along its boundaries. Thus road building and road maintenance are considerable threats to this lichen. The actual stream where *P. hydrothyria* occurs is still intact, as is the block of harvestable timber just around it (Frances Anderson pers. comm. August 2012). At the moment, cutting is not taking place in this block but it could come up for harvesting at any time.

At the West River Lake Brook site, Guysborough, Nova Scotia, a logging road crosses the stream over a culvert. Upstream of the road, the lichen is found within 1m of the road. Runoff from the road is visible downstream of the road and sediment occurs on the bryophytes. The first *P hydrothyria* colony appears after 120m. A series of S-curves appears to slow the progression of the runoff, which is evident even though the road is not currently being used for logging operations.

In August, 2012, the Port Hawkesbury mill received major funding from the province and approval from the Nova Scotia Utility and Review Board to commission an electricity cogenerating plant (Bundale 2012b). Nova Scotia Power is currently helping the mill to seek biomass suppliers for the 60-megawatt electricity generating facility. It will require about 500,000 tonnes of biomass fuel annually, now that it has begun operation in July 2013 (Simpson & Plourde 2011, King 2012, Erskine 2013). Additional leases on Crown and private land for cutting may be required to provide fuel.

The sixth location is Grays Hollow Brook at the northern end of Cape Breton where the threats are fewer than at the previous occurrences unless forestry activity upstream is initiated (Table 4). In this context, a second smaller (6-megawatt) biomass electricity generating plant is scheduled for construction at Syndney Harbour, Cape Breton, and is planned to begin generating electricity towards the end of 2014 (Albertstat 2012b).

The seventh location is at la Rivière Noire, la Forêt Montmorency, Québec, which is now within a protected area.

The search for new energy sources is now reaching into areas not previously exploited. This includes increased emphasis on biomass harvesting, extraction of natural gas through hydrofracturing, and the establishment of wind farms. In addition to direct impact, these require access roads through undisturbed woodlands that could disturb existing habitats of *P. hydrothyria* in all but three of the ten known occurrences (see Habitat Protection below).

Forest harvesting, mining and the development activities that alter the watercourses, water quality and protective surrounding habitat are increasing in Nova Scotia, New Brunswick and Québec. Currently, forest harvesters in Nova Scotia are only required to leave a 20m buffer on each side of streams. Three of the ten occurrences in N.S. either currently have clear-cuts near them or are in danger of suffering disturbance as a result of forestry activities within the next year or two. These are West River Lake Brook (c. 500 colonies of *P. hydrothyria*), Carter's Lake Brook (c. 100 colonies) and in a tributary of Beaver Brook in the Gerrish Valley (c. 100 colonies); together these occurrences contain c. 700 colonies of the total c.1282 enumerated mature individuals (colonies) (Table 2). Thus it is reasonable to predict that a >30% decline in the population of *P. hydrothyria* will occur over three generations (ca. 50 years). In addition there is gold mining activity near the Guysborough sites.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

There is currently no legal status or protection for *Peltigera hydrothyria*.

Non-Legal Status and Ranks

Global Status

The NatureServe Global Status is G4, 'Apparently Secure', but this assessment, in January 2008, was done before it was recognized that the taxon is composed of two distinct species: *P. hydrothyryria* and *P. gowardii*.

Status in Canada

In Canada, the Eastern Waterfan is ranked by NatureServe as SNR (unranked at a national or subnational conservation level: status not yet assessed). The General Status of Species in Canada lists it as May Be at Risk in Québec and also for Nova Scotia, and as Undetermined for New Brunswick. NatureServe lists the Waterfan as N2 (imperiled) for Canada as of 09 Sept 2011.

Status in the USA

This species complex has a national status of N3 Vulnerable. However, the eastern species, *P. hydrothyria,* is rated as S1, critically endangered in Virginia and S3, vulnerable in North Carolina. It has not been ranked in Connecticut or in the other USA states where it occurs, i.e., New Hampshire, Pennsylvania, Tennessee or Vermont (NatureServe 2012). In the eastern USA, *Peltigera hydrothyria* has disappeared from three New England States (Hinds & Hinds 2007) and is highly threatened there by pollution and habitat destruction, and further south by land-use conversion, habitat fragmentation, forest management practices and sedimentation (Southern Appalachian Species Viability Project 2002).

Habitat Protection and Ownership

Of the four New Brunswick occurrences of *P. hydrothyria*, two are currently protected as they are inside the Fundy National Park. The other sites have no protection as the streams flow through Crown and private land.

Two Nova Scotia occurrences are protected from direct resource extraction. The first is in Cape Chignecto Provincial Park and the second covers part of the Gray's Hollow Brook which flows out of the Pollett's Cove-Aspy Bay Wilderness Area. However, Gray's Hollow Brook flows through private and Crown land where it has no protection. There is another stream that flows into Cape Chignecto Park and meets up with the stream in which *P. hydrothyria* occurs and which has, as a result, been affected by forestry operations outside the park.

Where *P. hydrothyria* occurs on Crown land, its only protection is legislated riparian buffer requirements. Nova Scotia and New Brunswick have legislated buffer requirements of 20m and 30m respectively on each side of a watercourse but the effectiveness of these in maintaining water pH levels or stream-margin humidity is doubtful.

At the Guysborough occurrence, in Nova Scotia, there is currently logging within 3/4 km from where *P. hydrothyria* occurs on Crown land and harvesting leases exist all around it.

In Québec, there are forestry operations in the Laval University-managed Forêt Montmorency. The area near the occurrence was harvested some 10-15 years ago but the effects of harvesting are unknown since no estimate of the *P. hydrothyria* populations were made prior to 2011. This occurrence is now protected as a result of the Réserve de biodiversité projetée de la Forêt-Montmorency biodiversity conservation project.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Assistance with documenting the occurrence and distribution of *P. hydrothyria* in Canada has been provided by a large number of colleagues. We thank the following people for their generous help and time.

The report writers would like to thank Mr. Dave Fraser, Species & Ecosystems at Risk Section, Government of BC for help with the threats calculator exercise. They also thank Dr. Cathy Conrad and her assistants Ashley Shelton and Melissa Healey of the Saint Mary's University Community-Based Environmental Monitoring Network for the loan of portable water-monitoring equipment during the summer and fall of 2011. Fieldwork was carried out by Frances Anderson, David Richardson, Mark Seaward, Anne Mills, Stephen Clayden, Tom Neily, Ben Philips, Jean Gagnon and Claude Roy.

In Québec:

The report writers would like to thank Claude Roy, botanist at l'Herbier Louis-Marie, Université Laval; and Jean Gagnon, Ministère du Développement durable, de l'Environnement et des Parcs, Direction du patrimoine écologique et des parcs, for information, guidance and assistance in the field.

In New Brunswick:

The report writers would like to thank Stephen Clayden, New Brunswick Museum, Saint John; Dan Mazerolle, Monitoring Ecologist, Fundy National Park; and Ben Phillips, Conservation Project Manager, Fundy Biosphere Reserve for their help with fieldwork and information with respect to New Brunswick.

In Nova Scotia:

The report writers would especially like to thank Tom Neily for making available his records of *P. hydrothyria* from his extensive surveys of cyanolichens in Nova Scotia and for accompanying Frances Anderson on some of the field excursions. We also thank Anne Mills in this respect and for identifying bryophytes collected from *P. hydrothyria* streams.

Assistance with documenting the occurrence and distribution of *P. hydrothyria* in Canada has been provided by a large number of colleagues including:

Canada: Sean Blaney, Irwin Brodo, Stephen Clayden, Trevor Goward, Claudia Hanel, Janet Marsh;

Finland: Ted Ahti;

USA: Sean Beeching, Scott LaGreca, Don Flenniken, Alan Fryday, Jim Hinds, Jody Hull, James Lendemer, Philip May, Garry Perlmutter;

Roger Rosentreter, Nancy Slack, Cliff Wetmore;

UK: Mark Seaward.

The personal communications cited in the text were all received by email in 2011 and 2012. We thank all colleagues for their generous help and time.

INFORMATION SOURCES

Agren, A., Buffam, I., Bishop, K and Laudon, H. 2010. Sensitivity of pH in a boreal stream network to a potential decrease in base cations caused by forest harvest. Canadian Journal of Fisheries and Aquatic Science 67:1116-1125.

Agriculture & Agri-Food Canada (2013) Beneficial Management for riparian zones in Atlantic Canada. http://www.nr.gov.nl.ca/nr/publications/agrifoods/beneficial.pdf, pp 34-36.

Ahmadjian, V. 1989. Studies on the isolation and synthesis of bionts of the cyanolichen *Peltigera canina* (Peltigeraceae). Plant Systematics and Evolution 165:29-38.

Alberstat, J. 2012a. Developer to seek OK for wind farm in Cobequid Hills.Business Section, Chronical Herald, Halifax, 20th Feb. www.wind-watch.org.

Albertstat, J. 2012b. Biomass plant in works. Chronical Herald, Halifax, 6th Oct. C 1-3.

Anderson, F. 2004-2007. Cape Chignecto Provincial Park Field Reports (unpublished) submitted to the Nova Scotia Department of Natural Resources.

Anonymous 2011. Onshore Petroleum Agreements: http://www.gov.ns.ca/energy/resources/RA/maps/onshore-petroleum-agreements.pdf

Bailey, R.H. and James, P.W. 1979. Birds and the dispersal of lichen propagules. Lichenologist 11:105-106.

Beauchamp, S., Tordon, R. and Pinette, A. 1998. Chemistry and deposition of acidifying substances by marine advection fog in Atlantic Canada. In Proceegings of the First International Conference on Fog and Fog Collection (R. S. Schemenauer and H. Bridgman eds)., Vancouver, Canada, July 19-24., pp. 171-174.

Blondeau, M., C. Roy and Cuerrier, A. 2011. Plantes des villages et des parcs du Nunavik. Institut culturel Avataq et Éditions Multimondes, 737pp. (trilingue: français, anglais et inuktitut).

Baldwin , L.K. and G.E. Bradfield. 2005. Bryophyte community differences between edge and interior environments in temperate rain-forest fragments of coastal British Columbia. Can. J. For. Res. 35: 580–592.

Brodo, I.M., Sharnoff, S,D., and Sharnoff, S. 2001. Lichens of North America. Yale University Press, New Haven, 795pp.

Bundale, B. 2012a. Energy Company: Exploration didn't cause N.B. quake. Chronicle Herald, March 13: C1.

Bundale, B. 2012b. Mill gets millions in N.S. cash. http://thechronicleherald.ca/novascotia/128302-mill-gets-millions-in-ns-cash. August 20.

Burns, D.A., Lynch, J.A., Cosby, B.J., Fenn, M.E. and Baron, J.S. 2011. National Acid Precipitation Assessment Program Report to Congress 2011: An Integrated Assessment. US EPA Clean Air Markets Division, National Science and Technology Council, Washington, DC, 114 p.

Cameron, R.P. 2006. Protected Area-working forest interface: concerns for protected areas management in Canada. Natural Areas Journal 26:403-407.

Cameron, R.P. and Richardson, D.H.S. 2006. Occurrence and abundance of epiphytic cyanolichens in Nova Scotia protected areas. Opuscula Philolichenum 3:5-14.

Casamatta, D.A., Gomez, S.R. and Johansen, J.R. 2006. *Rexia erecta* gen. et sp. nov. and *Capsosira lowei* sp. nov. two newly described cyanobacterial taxa from the Great Smokey Mountains National Park (USA). Hydgrobiologia 561:13-26.

CCME 2004, 2011. Canadian Acid Deposition Science Assessment and Summary. https://www.ec.gc.ca/Publications/default.asp?lang=En&xml.

CESCC 2011. Wild Species 2010: The General Status of Species in Canada. Canadian Endangered Species Conservation Council. National General Status Working Group, 302pp.

Clair,T.A., Dennis, I.F., Scruton, D.A., and Gilliss, M. 2007. Freshwater acidification research in Atlantic Canada: a review of results and predictions for the future. Environmental Reviews 15:153-167.

Clayden, S.R. 2010. Lichens and allied fungi of the Atlantic Maritime Ecozone. In Assessment of species diversity in the Atlantic Maritime Ecozone. (D.F. McAlpine, and I.M. Smith eds.) NRC Press, Ottawa, pp. 153-178.

Clayden, S.R., Cameron, R.P. and McCarthy, J.W. 2011. Perhumid boreal and semiboreal forests of eastern Canada. In Temperate and boreal rainforests of the world: ecology and conservation (D. DellaSala, ed.) Island Press, Washington, DC., pp. 111-131.

COSEWIC 2013. Definitions, In Operations and Procedures Manual, Committee on the Status of Endangered Wildlife in Canada, Environment Canada, August 2013, Appendix C, pp. 144-154.

Davis, W.C., Gries, C. and Nash, T.H. 2000. The ecophysiological response of the aquatic lichen *Hydrothyria venosa* to nitrates in terms of weight loss and photosynthesis over long periods of time. Bibliothica Lichenologica 75:201-208.

Davis, W.C., Gries C and Nash, T.H. 2003. The influence of temperature on the weight and net photosynthesis of the aquatic lichen *Peltigera hydrothyria* over long periods of time. Bibliotheca lichenological 86:233-242.

Dennis, W.M., Collier, P.A., De Priest, P. and Morgan, E.L. 1981. Habitat notes on the aquatic lichen *Hyrothyria venosa* Russell in Tennessee. Bryologist 84(3):402-403.

Dube, S., Plamondon, A.P. and Rothwell, R.L. (1995) Watering up after clear cutting on forested wetlands of the St Lawrence Lowland. Water Resource Research 31:1741-1750.

Entrekin, S., Evans-White, M., Johnson, B. and Hagenbuch, E. 2011. Rapid expansion of natural gas development poses a threat to surface waters. Frontiers in Ecology and the Environment 9:503–511.

Erskine, B. 2013. NSP biomass site aims for 4%of power needs of N.S: plant in operation after test. Chronicle Herald, Halifax, B2, July 3rd.

Esslinger, T.L. 2010. A cumulative checklist for the lichen forming, lichenicolous, and allied fungi of the continental United States and Canada. North Dakota State University. http:// WWW.ndsu.edu/pubweb/~esslinge/chcklst.

Faubert, J. 2007. Catalogue des bryophytes du Québec et du Labrador, Provancheria no 30, Mémoire de l'Herbier Louis-Marie, Université Laval, 138pp.

Favreau, M. et G.R. Brassard. 1988. Catalogue Bibliographique des Bryophytes du Québec et du Labrador. Département de biologie, Memorial University of Newfoundland, St-Jean, Terre-Neuve, Canada.

Gilbert, O.L. 1986. Field evidence for an acid rain effect on lichens. Environmental Pollution, Series A 40:227-231.

Gilbert, O.L. and V. J. Giavarini. 1997. The Lichen Vegetation of Acid Watercourses in England. The Lichenologist. The Lichenologist 29: 347-367.

Glavich, D.A. 2009. Distribution, rarity and habitats of three aquatic lichens on federal land in the US Pacific Northwest. Bryologist 112:53-58.

Glime, J.M. 1984. Physio-ecological factors relating to reproduction and phenology in *Fontinalis dalecarlica*. Bryologist 87:17-23.

Goudie, A. 2006 Human impact on the natural environment. Blackwell, Oxford.

Gowan, S.,P. and Brodo, I.M. 1988. The lichens of Fundy National Park, New Brunswick, Canada. Bryologist 91:255-0325.

Goward, T., Brodo, I.M. and Clayden, S.R. 1998. Rare Lichens of Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, 74pp.

Hale, M.E. 1969. How to know the lichens. Wm. C Brown, Dubuque.

Hawksworth, D.L. 1983. A key to the lichen-forming, parasitic, parasymbionts and saprophytic fungi growing on lichens in the British Isles. Lichenologist 55:1-44.

Hinds, J. W., and Hinds, P. L. 1998. An annotated checklist of Maine macrolichens. In Lichenographia Thomsoniana: North American Lichenology in Honor of John W. Thomson. (M. G. Glenn, R. C. Harris, R. Dirig, and M. S. Cole eds),. Mycotaxon Ltd., Ithaca, NY., pp. 345-376.

Hinds, J.W. and Hinds, P.L. 2007. The Macrolichens of New England. New York Botanical Garden Press, New York, pp. 47-57.

Hinds, J. W., Fryday, A. M., and Dibble, A. C. 2009. Lichens and bryophytes of the alpine and subalpine zones on katahdin, Maine, II: Lichens. Bryologist 112:673-703.

Honegger, R. 2008. Morphogenesis. In Lichen Biology, 2nd Edit. (T.H. Nash ed.) Cambridge University Press, Cambridge p.69-93

Hylander, K. 2005. Aspect modifies the magnitude of edge effects on bryophyte growth in boreal forests. Journal of Applied Ecology 42: 518–525.

Hylander, K, B.G. Jonsson, and C. Nilsson. 2002. Evaluating buffer strips along boreal streams using bryophytes as indicators Ecological Applications 12: 797-806.

Jacobs, J.B. and Ahmadjian, V. 1973. The ultrastructure of lichens, V. *Hydrothyria venosa*, a freshwater lichen. New Phytologist 72:155-160.

Kele, A.K. 1964.Isolation of the mycobiont and phycobiont of an underwater lichen, *Hydrothyria venosa*. Honours thesis Clark University (Worcester, Mass.), 86 p.

King, N. 2012. Nova Scotia Power wants to talk to potential biomass suppliers. Cape Breton Post Business Section, 20th September.

Lange, O,L., Killian, E., and Ziegler, H. 1986. Water vapour uptake and photosynthesis in lichens: performance differences in species with green and blue-green algae as phycobionts. Oecologia 71:104-110.

Larsson, P. and Gauslaa, Y. 2010. Rapid juvenile development in old forest lichens. Botany 89:65-72.

Lattman, H., Lindblom, L., Mattson, J., Milberg, P., Skage, M. and Eckman. S. 2009. Estimating the dispersal capacity of the rare lichen *Cliostomum currugatum*. Biological Conservation, 142(8):1870-1878.

Lee, P., Smyth, L., Boutina, S. (2004) Quantitative review of riparian buffer width guidelines. Journal of Environmental Management, from Canada and the United States 70:165-180.

Lendemer, J.C. and Anderson, F. 2012. Molecular data confirm the identity of populations of the waterfan lichen from eastern Canada as *Peltigera hydrothyria s.* str. Opuscula Philolichenum 11:139-140.

Lendemer, J.C. and O'Brien, H.O. 2011. How do you reconcile molecular and non-molecular datasets? A case study where new molecular data prompts a revision of *Peltigera hydrothyria* s.l. in North America and the recognition of two species. Opuscula Philolichenum 9:99-110.

Levine, J.M. 2001. Local interactions, dispersal, and native and exotic plant diversity along a California stream. Oikos 95:397-408.

Likens, G.E., Bormann, F.H., Johnson, N.M., Fisher, D.W. and Peirce, R.S. !970) Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecological Monographs 40:23-47.

Miadlikowska, J., and Lutzoni, F. 2000. Phylogenetic revision of the genus *Peltigera* (lichen forming Ascomycota) based on morphological, chemical and large subunit nuclear ribosomal DNA data. International Journal of Plant Science 161:925-958.

Muraca, G., MacIver, D.C., Auld, H. and Urquizo, N. 2001. The Climatology of Fog in Canada. In Proceedings of the 2nd International Conference on Fog and Fog Collection, St. John's, Newfoundland, 15-20 July, 2001.

Nash III, T.H. 2008. Lichen Biology, 2nd Edit. Cambridge University Press, Cambridge.

NatureServe 2013. A network connecting science with conservation. http://www.natureserve.org.

Nieboer, E., MacFarlane, J.D. and Richardson, D.H.S.1984. Modifications of plant cell buffering capacities by gaseous air pollutants. In: Gaseous air pollutants and plant metabolism (M. Koziol & F.R. Whatley, eds), Butterworths, London, pp. 313-330.

Nova Scotia Department of Natural Resources. (2002). *Wildlife Habitat and Watercourses Protection Regulations, Forests Act N.S. Reg. 166/2002, Halifax, Nova Sciatia* http://www.novascotia.ca/just/regulations/regs/fowhwp.htm

Percy, J.A., Evans, A.J., Wells, P.G. and Rolston, S.J. 2005. The changing Bay of Fundy: Beyond 400 years. Bay of Fundy Ecosystem Partnership. Environment Canada, Dartmouth.

Richardson, D.H.S. 1992. Pollution Monitoring with Lichens. Richmond Publishing, Slough.

Richardson, D.H.S. and Cameron, R.P. 2004. Cyanolichens: their response to pollution and possible management strategies for their conservation in northeastern North America. Northeastern Naturalist 11:1-22.

Russell, J.L. 1853. *Hydrothyria venosa*; a new genus and species of the Collemaceae. Proceedings of the Essex Institute 1:188-191.

Scheidegger, C. and Goward, T. (2002) Monitoring lichens for conservation: red lists and conservation action plans. In Monitoring with lichens – Monitoring lichens (P.L. Nimis, C. Scheidegger and P.A. Walseley, eds.) Kluwer Academic, Dordrecht pp. 163-181.

Schneider, A. 1897. A textbook of general lichenology with descriptions and figures of the general occurring in the northeastern United States. Willard Clute, Binghamton.

Seaward, M.R.D. 2008. Environmental role of lichens. In Lichen Biology, 2nd edition. (T.H. Nash, ed), Cambridge University Press, Cambridge, pp. 274-298.

Simpson, J and Plourde, R. 2011. Nova Scotia achieves the worst possible scenario for biomass energy. Ecology Action Centre, Jan. 26. Halifax.

Southern Appalachian Species Viability Project 2002. A partnership between the U.S. Forest Service, Region 8, Natural Heritage Programs, NatureServe and independent scientists to review data on rare species in the Southern Appalachian and Alabama region. Data base provided by Nature Serve, Durham, North Carolina.

Stewart K.J. and A.U. Mallik. 2006. Bryophyte responses to microclimatic edge effects across riparian buffers. Ecological Applications 16:1474-1486.

Tremblay, Y., Rousseau, A.N., Plamondon, A.P. Levesque, D. and Prevost M. 2009. Changes in stream water quality due to logging of the boreal forest in the Montmorency Forest, Québec. Hydrological Processes 23:764-776.

Vasseur, L. and Cato, N. 2008. Atlantic Canada. In From impacts to adaptation: Canada in a changing climate (D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush, eds.), Government of Canada, Ottawa, pp. 119-170.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

David Richardson is Dean Emeritus at Saint Mary's University. He has studied lichens since 1963 and as sole author written two books on lichens: The Vanishing Lichens and Pollution Monitoring with Lichens. He has also completed over twenty book chapters and 100 research papers on various aspects of lichenology. He has studied lichens in Australia, Canada, Ireland and the United Kingdom.

Frances Anderson is a Research Associate at the Nova Scotia Museum of Natural History, Halifax. She has been carrying out field work on lichens in Nova Scotia for more than five years and has extensive experience in doing field inventories. She is currently working on a macrolichen checklist for the Province.

Robert Cameron has been studying lichens for over ten years beginning with a Master's degree in Biology at Acadia University studying the effects of forestry practices on lichens. More recently, Mr. Cameron has been studying the effects of air pollution on lichens, coastal forest cyanolichens and more specifically boreal felt lichen. He is currently the ecologist with Protected Areas Branch of Nova Scotia Environment and Labour, responsible for the protected areas research program.

COLLECTIONS EXAMINED

The following herbaria/websites were consulted with respect to records of *P. hydrothyria:*

Farlow Herbarium, Boston

Herbarium of the New Brunswick Museum, Saint John

Canadian Museum of Nature, Ottawa

New York Botanical Garden

Smithsonian Museum, Washington

The Consortium of North American Lichen Herbaria CNALH (http://lichenportal.org/portal) Herbier Louis-Marie, Université Laval, Québec City

The Nova Scotia Museum, Halifax

In addition, the American and international lichenologists listed above in the Acknowledgements were contacted for details of *P. hydrothyria* collections lodged in their private or university herbaria.

Appendix 1. GPS and other information on the sites in Canada where *Peltigera hydrothyria* has been found in the provinces of Nova Scotia, New Brunswick and Québec.

Site name of stream	Year found	Most recent survey	Estimated number of colonies	Elevation	Stream pH	% of stream searched	Ownership / Protection
NEW BRUNSWICK							
Black Brook, Fundy National Park	1980	July 2011	5	248-252m	6.8-7.1	30%	National Park
Dickson Brook, Fundy National Park	2013	July 2013	200	66-94	7.2-7.3	70	National Park
Daniels Brook, Shepody Mtn	1978	Sept 2011	77	90-165m	6.9	95%	Shepody Mountain, private
Hamilton Creek West, Shepody Mtn	2011	Oct 2011	2	220m	DNC	DNC	Shepody Mountain, NB Crown
NOVA SCOTIA							
Eatonville Brook, Cape Chignecto	2006	July 2011	200+	51-20m	6.7-7.4	56%	Cape Chignecto Provincial Park
Carter's Lake Brook, Folly Lake, Cobequid Mtns		May, July, Aug 2011	120+	241-200m	5.7-6.0	38%	Private
Carter's Lake Brook tributary, Folly Lake, Cobequid Mtns		May, July 2011	30	240-230m	5.7	30%	Private
West River Lake Brook, Guysborough co	2011	Nov, Dec 2011	500+	155-120m	6.2-5.6	100%	NS Crown
Melopseketch brooklet, Guysborough Co	2011	Dec 2011	1	149m	5.6	100%	Crown
Embree's Brook tributary, Port Hawksbury	2008	Sept 2011	12	74-61m	7.1	10%	Crown?
Gray's Hollow Brook, North River, Cape Breton	2008	Sept 2011	23	63m	7.5	25%	Pollett's Cove-Aspy Bay Wilderness Area
A tributary of Beaver Brook in the Gerrish Valley, Colchester Co		2012	100+	149 - 202m	6.9	45%	Private
QUÉBEC							
Rivière Noire Montmorency Co	1990	Aug 2012	12	723m 717m	6.3	10%	Managed forest, Laval University